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THE TECHNIQUE OF PASTURE MEASUREMENT

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(*Received for publication, May 1949*)

Summary

The paper gives a general discussion of factors involved in pasture measurement. The effects upon pasture growth of animal excrement and the grazing of stock are discussed, and the effects of mowing and grazing are compared.

It is concluded that the herbage production capacity of a mixed sward, and the influence of one species upon another can be measured efficiently only under grazing.

The following techniques of pasture measurement are described and discussed with examples: observational plots; single plant studies; mown plots: plots alternately mown and grazed; paddock trials with protected measurement cages; plots grazed with a proportional return of dung and urine. Also discussed are methods of determining herbage composition and the relationship between ground cover and actual yield of botanical constituents of the sward.

INTRODUCTION

It is axiomatic that the value and efficiency of any pasture experimental work depends not only on the precision of the work itself but also on the extent to which the technique used makes the results applicable in actual farming practice. It is regrettable that with much pasture measurement work considerable difficulty arises in the interpretation of the results, because trial conditions have been widely separated from those actually operating under normal grazing. Several points of departure of experimental conditions from field practice can be seen in various recent published methods of pasture measurement. Most of these are associated with the difficult task of trying to equate yields records from the use of the mower, with the amounts of herbage taken up by the animal in grazing, and with the effects of this herbage upon the animal. This involves consideration of the effect of defoliation by the mower as compared with animal grazing, the tramping of the grazing animal and also the influence of the stock manure returned during such grazing. Before discussing the different techniques in use at the Grasslands Division it is proposed to consider some of the points in detail, so that the differences between these various techniques can better be appreciated.

FACTORS INFLUENCING CONDITION OF PASTURE SWARD

The Effect of Dung and Urine on the Sward

The grazing animal retains very little of the minerals or nitrogen of the herbage for its own use. After taking the digestible energy and retaining small amounts of the plant's nutrients, the animal returns the remainder to the sward in the dung and urine. This retention varies with different classes of stock; for instance a fattening sheep retains only about 4 per cent of nitrogen and ash constituents, whilst a milking cow retains up to about 25 per cent of the nitrogen and 10 per cent of the ash constituents for its growth and milk supply (1).

The effect on the pasture of the return of such large amounts of quick acting plant nutrients can readily be seen in the field, and also in comparisons of yield and composition of pastures under mowing with those under grazing.

For some years, measurements of the effects of dung and urine both separately and together, have been carried out at Grasslands Division by the author (2, 3). In one trial it was found that the manurial value of the dung and urine from mature wethers grazing a pasture producing 14,000 lb of dry matter (D.M.) per acre per annum, was the equivalent of approximately 24 cwt of sulphate of ammonia, 18 cwt of 30 per cent potash, 6 cwt of superphosphate, and 3 cwt of carbonate of lime. Urine encouraged grass growth due to its large content of nitrogen and potash, while the dung, which contains almost all the phosphate and lime together with some slow-acting nitrogen and potash, encouraged primarily the clover, and then later, the grass. Where both dung and urine were returned the sward developed into a balanced perenial ryegrass: white clover sward yielding 14,000 lb of dry matter per acre per annum, but where neither was returned the sward was dominantly white clover, and the yield was much lower (10,000 lb of dry matter per acre per annum). In the latter two years of the trial, there was an appreciable increase in the grass content of the "no return" paddocks, presumably due to the increase in the soil nitrogen content from the action of the early vigorous growth of the clovers. A second trial in which clover was excluded from the sward showed yields of approximately 1,500 lb of dry matter per acre for the treatment not receiving any dung or urine, but yields of 3,500 lb of dry matter per acre were recorded for the treatment receiving the return (4). In both trials the drain of phosphate and lime was compensated for by the use of artificial fertilizers, and thus the greater differences in the latter trial compared with the former, show the great value of the clovers of the sward in making up, partially at least, for the nitrogen loss by the non-return of the urine and dung. It is therefore obvious, from the point of view of herbage and also of the botanical and chemical composition of the swards, that measurements made under mowing without returning the dung and urine or their equivalent in artificials would be vitiated, and comparisons of manurial effects, etc. under such conditions would be invalid (the author has not yet found a combination of artificials which duplicates exactly the effect of dung and urine).

It is important also to consider the actual habits of the animal associated with the passing of the dung and urine.

(1) It would appear from experimental data secured in connection with feeding trials at this station and from other work, that the grazing animal eats the largest proportion of its food during the day, but passes

the largest proportion of its dung and urine during the night. Also the habit of "camping" in particular places, especially along fence boundaries on small enclosures, results in large amounts of dung and urine being deposited on these areas.

(2) Both urine and dung are passed in a series of "doses" or "dollops" on to the sward. This results in concentrations of urine at some points and of dung at others. Urine contains large amounts of quick-acting nitrogen and potash; a large "dose" of this results in a quick growth of grass and a suppression of clover growth at that point. Whether this suppression of the clover is due directly to the strong competition of the grass which responds very quickly to such nitrogen, or to a direct deterrent to clover growth is not yet clear, and trials are in progress to elucidate this point. The evidence to date is that it is a combination of these two factors. An example of the inhibiting effect on clover growth, is seen in the extra suppression of clover in lawns when potash salts were used in addition to sulphate of ammonia (5). Moreover, at Grasslands Division, with pasture plots laid down about 18 months ago, where nutrients are applied to swards of perennial ryegrass, white clover, and mixtures of these species, in amounts to equal those returned in normal grazing of very high production swards (14,000-18,000 lb of dry matter), it has been seen that the potash has a definite inhibiting effect on the pure white clover swards but does not affect the perennial ryegrass. In the mixed pasture the combinations of nitrogen and potash gave a definite increase in the grass : clover ratio compared with nitrogen alone (6).

It has been estimated at Grasslands Division that in the case of wethers the average urination amounts to about 150 ml. As such animals normally stand still during this process the 150 ml. of urine fall on an area of approximately 36 sq. in. The normal concentration of nitrogen in urine is approximately 1.0 per cent, and of potash (as K_2O) 1.1 per cent. Thus, in those places the amount is equal to a dressing of approximately 25 cwt sulphate of ammonia and 19 cwt 30 per cent potash salts per acre. While the reason for clover suppression is not evident, it is apparent that such urine patches develop into grass dominance, and it is rather interesting and important that the dominance of perennial ryegrass over a good white clover, in a grazed pasture, is a function both of the amount and composition of the animal droppings as well as the way in which they are distributed by the animals.

From the above calculations and also from field observation it can also be found that in an *evenly* grazed sward each point will receive *on the average* less than one dressing of urine per annum. It has been observed at Grasslands Division that the effect on grass growth of such urine patches lasts about 2 to 3 months only. The fate of the total amount of nitrogen applied at such heavy rates has not yet been determined, but it would appear that there is a considerable loss from the soil. The efficiency of the recovery of this applied nitrogen will depend not only on the soil conditions but also on the time of year and the potentiality for further growth of the grass plants present in the sward. Thus, as an extreme case, there will obviously be much more loss if urine is applied to paspalum in the winter when this species is relatively dormant, than would be the case if the application were made to Italian ryegrass which has a much higher potential production at that time of the year. The position would be reversed in the late summer period when paspalum is growing vigorously and Italian ryegrass is dormant. The position is further complicated by the similar patchiness of the dung applications,

As this dung contains almost all the phosphate the position could develop on a phosphate deficient soil that the full value of the nitrogen of the urine patches is not obtained because there is insufficient available phosphate at that point to cater for the high induced nitrogen level, although there may have been enough to provide for a reasonably good clover dominant sward.

It also follows from the above calculations that if any particular patch receives its dose of urine only once in nearly two years, and if the effects of this urine last only for a few months, then for the remainder of the period such a patch must obtain its nitrogen supply direct from the soil. This nitrogen is built up in the soil through the medium of the clover rhizobia and/or of the free-living nitrogen-fixers. The importance of getting the clovers strong enough to act as a balancing medium in the sward without being eliminated completely in the patches cannot be overstressed in all pasture work.

(3) Variations in the distribution and composition of dung and urine occur with differences in animals, feed quality, and weather conditions. The retention of nutrients varies with the class of stock as mentioned, but also the quality of the urine varies directly with that of the feed supply. Furthermore, concentration of the urine changes with the weather, being very dilute when the herbage is wet or low in dry matter, and more concentrated in dry conditions. The amounts passed by cows are, of course, much greater than those passed by sheep, and thus the patches are larger in extent though smaller in number; also, the cow's habit of facing away from the wind compared with the ewe's habit of facing into the wind while urinating, results in a much greater spread of the cow's urine in windy weather, than occurs with the ewe.

The effects of differential concentrations of droppings within the paddock can be seen in the variance of general pasture composition and growth. The concentrations at the night "camping" places have been mentioned but similar areas of concentration occur in the vicinity of shelter, drinking water, and gateways.

Where paddocks are adjacent to roadways it is usual to find an induced fertility slope rising from the road boundary towards the other side of the paddock. This is brought about by the road traffic frightening the stock away and at the end of such a retreat it is usual for the animal to pass urine and dung.

(4) In addition to the above points there is the fact that the herbage around dung patches is usually unpalatable until the dung has dried out or washed into the soil, but urine does not appear to affect the palatability of the herbage directly.

This dung effect can be seen clearly in any pasture just after grazing when the herbage around dung patches is noticeably avoided. In the experiment mentioned above, comparing the effects on growth of dung and urine, it was noticeable that the paddocks to which urine only was returned were grazed much more readily than were the pastures to which dung was returned. In paddock measurements, dealt with later on in this paper, where areas are protected from grazing and then cut to measure herbage growth, it has been found desirable to spread back on to these cut areas a mixture of dung and urine in order to prevent overgrazing which would happen if such areas were not so treated.

(5) There is a considerable carry-over of dung and urine in the animal's body for some time after food is ingested. From feeding trials using markers it would appear dung is excreted in maximum quantity

at approximately 24 hours after feeding and continues to be excreted in quantity for another day or so. Urine comes through much more quickly and a large carryover for more than a day is unlikely. An animal grazing a paddock for a short period would, therefore, return to the pasture a large proportion of the dung and urine resulting from previous grazings.

These materials vary considerably in quantity and in composition, and it is very easy to change the soil fertility of a paddock by stock manipulation.

(6) Dung and urine held in storage at other than very low temperatures, lose a considerable amount of nitrogen as ammonia, especially if they are mixed together. These losses can be very high, e.g. up to 30-40 per cent, in hot weather.

Effect of Grazing

Because of differing palatability of the various species, diversity of animals' habits, and the hunger of the animals used, the effect of grazing on a pasture differs considerably from that of mowing. There is, for instance, a wide variation in the performance of the different species under different treatments. With mowing, for instance, the performance of a species may differ considerably from that of the same species with grazing, even though soil fertility conditions are the same.

Illustrative of the differences in yield and composition which can be obtained, are the results secured in the following simple trial carried out by the writer at Grasslands Division (4). A comparison of the yields under similar conditions, from mowing and from sheep grazing was made possible by fixing on the sheep a special collecting apparatus (3) which prevented the return to the pasture of dung and urine. Results for the period May 1947 to May 1948, the second year of the trial period, are shown in Table I.

The technique used for the measurement under grazing was to cut a mower strip out of the plots prior to grazing, as for the mowing trial.

TABLE I. YIELDS AND COMPOSITION OF PASTURE MEASURED UNDER MOWING AND UNDER SHEEP GRAZING WITHOUT RETURN OF DUNG OR URINE

	Mowing.					Sheep Grazing.				
	Yields of Dry Matter per Acre.				Relative Yields.	Yields of Dry Matter per Acre.				Relative Yields.
	Grasses.	White Clover.	Red Clover.	Total.		Grasses.	White Clover.	Red Clover.	Total.	
Grasses Only										
Actual	1586	—	—	1586	100	1454	—	—	1454	—
*Adjusted for grazing						1575	—	—	1575	100
Grasses and Clovers										
Actual	3301	5638	1966	10927	688	2328	4505	897	7730	
*Adjusted						2422	4880	972	8474	538

* Adjusted by increasing grazed area yields by 1/12th to compensate for loss of yield during actual grazing.

The product of the mown strip was returned to each respective plot and this, plus the balance of the herbage, was eaten by the sheep until such time as the mown strips could not be distinguished. This took approximately 2-2½ days at each grazing, so that the yields obtained for this block were lowered by the loss of the growth during the actual grazing time. The figures have therefore been corrected by adding to the yields obtained, an amount proportional to the time (1/12th of the period) under grazing (by direct calculation). This addition, however, is actually small and even if not quite correct would not invalidate the conclusions drawn by comparing the two sets of totals.

It can be seen that under grazing the yield of the more palatable grass and clover mixture has differed considerably from the yield of the same mixture under mowing. This is especially noticed in the red clover. The difference is largely due to the fact that the sheep chewed the pasture down much harder than it was cut by the mower even though the mower was set as low as the general grazing height. The result on the more susceptible red clover with its single crown, has been the virtual elimination of this species from the mixture. However, the same general effect is seen in the other species in these plots, although the relative depression of yield is not so marked as in the red clover. There was probably some additional total depression of the yield from the damage to the sward by the trampling of the stock during wet weather. With the pure grass series, the fact that, due to lack of thrift, they were unpalatable without the clover did not result in any excessive grazing; indeed, these plots occasionally had to be trimmed with the mower after grazing, to bring the total sward-level down to the mower cut height. The overall effect is to show a much greater relative difference in yields between the treatments under mowing than under grazing, although it is evident in this case, that both sets of figures are convincing.

Effect of Trampling

This also can bring about a difference in pasture performance. Excessive trampling can lead to actual killing of plants as well as the disturbance of soil structure and water relationships. On the other hand moderate consolidation, or "hoof cultivation" is a desirable feature of the grazing animal and undoubtedly aids the establishment, tillering, and growth of some species. This is especially noticeable with perennial ryegrass. This plant needs the constant pressing of its crown into the ground, and the particular cutting and pressing action of the hoof of an animal appears to suit it admirably.

Clear examples of the response of perennial ryegrass to consolidation can be seen in paddocks across which are tracks made by motor or other traffic. Similarly, the line of ryegrass growth which shows up beneath a clothes line in the average household back lawn is undoubtedly due to the treading action of the person hanging out the washing.

A significant result of the effect of *lack* of animal treading has recently shown up in the series of plots considered in Table I.

In both the mown and the grazed series the early effect of added phosphate in maintaining a vigorous growth of clovers was measured. Because of the non-return of dung and urine to these plots the growth of grass was very much less than on the series that did receive the return. Later, however, due to the build-up in soil nitrogen direct in the soil from the clover, there was an increase in the grass content. This was most marked in the winter period, and especially in the phosphated

series. Up to last winter (1948) both the mown and grazed (without return) series ran parallel in growth and composition. During late winter, however, it was seen that in the mown series there was a vigorous growth of *Poa trivialis* in the bottom layer, out of reach of the mower. In the grazed series this did not occur due to the physical opening up of the sward by the animals trampling the soft ground and grazing down very closely.

This growth of *Poa trivialis* on the mown series was followed by the development of browntop, another close-growing species. The net result of invasion by these two species has been a depression of the perennial ryegrass and the clover growth in these plots. The depression was probably caused by a shading of the crown of the plants and the prevention of tillering and of rooting at the nodes. The grazed series, on the other hand, have a clean open bottom and the growth of clovers and perennial ryegrass is very good, with a strong response to added phosphate showing up very clearly. In the mown plots the reverse now obtains. Because there was a greater invasion of the bottom grasses into the phosphated plots this resulted in a greater suppression of the ryegrass and clovers here than in the others. The result is that at the present time (Spring, 1948) there is a depressing effect from the added phosphate because of the suppression of those species which should be growing well at this time, if the real effect in the sward is to be measured. It should be mentioned, however, that in the parallel treatments which do receive dung and urine, there is no such difference as above between the grazed and mown series. This is undoubtedly due to the fact that the very high soil fertility resulted in a vigorous growth of perennial ryegrass and clover right through the trial. This prevented the invasion by the bottom species simply by the rapid recovery of the perennial ryegrass and white clover as well as the open nature of the bottom resulting from the erect tall growth of such high-producing swards which naturally have the same interval between cuttings as the lower-producing series.

It is thus apparent that pasture measurement is best carried out in actual grazing paddocks or with a plot technique which incorporates the grazing animal or its effects to the full; this is particularly so if reliable total yields and compositions of mixed pasture swards are desired, and also if the interaction of species of mixed swards under different manurial and management systems is being studied. However, there are plenty of circumstances in which other less involved techniques are of value, and yield results which are quite valid for each particular purpose.

The essential thing is to give full consideration to the validity and limitation of any particular technique being used on the trial itself.

DESCRIPTION OF TECHNIQUES USED

Following is an outline of some of the techniques which are in use or which have been tried out in this country, as well as a few observations on their validity and limitations.

Observational Trials

Much maligned as it is, the system of laying down plots or paddocks with various seeds or fertiliser mixtures and keeping a close watch on the performance has been, and still is, a very valuable adjunct to any measurement work.

In the hands of skilled and unbiased observers the method gives wide scope to obtaining very valuable information. The difficulty, of course, lies in the variety of opinions the values of which will usually be assessed on the basis of the scientific reputation of the person holding the opinion. However, it cannot be denied that very useful "pointers" for measurement have come and will come from such work.

Single Plant Studies

As an integral part of the plant breeding work, species are put out as single plants for selection and progeny testing. Field notes on vigour, persistency and palatability have given, especially where reinforced by actual weights, information which so far has checked very well with relative performances in the field. A difficulty with such work arises in comparisons between species. Some species perform much better as single plants (e.g. timothy and cocksfoot) than when in a mixed sward, and so in the main, performances as single plants have to be checked against grazed plots and paddocks under different management systems. The results secured by Corkill (7) in his plant breeding work at Grasslands show that his judgment, based on single plant studies and checked in the field, has been remarkably good.

Simple Mowing Trials

The simple mowing trial for measuring manurial effects on a mixed sward was early tried and discarded by Hudson (8) on account of the loss of soil fertility and the reversion of the sward to weeds. Lynch (9) has since introduced a variation insofar as he returned the clippings direct to the sward. This is claimed as a reasonably reliable method of maintaining the sward where climatic conditions are suitable for the decomposition of such clippings. The Grasslands Division was associated with some of these trials, carrying out the botanical work. In view of the amounts of dead herbage found in each subsequent cut, and the rapid deterioration of the sward to one dominantly of *Poa trivialis* and Yorkshire fog, this method appears to have considerable limitations. The loss of the ryegrass and clovers in these swards was undoubtedly due to the dank conditions and absence of light resulting from the lack of grazing and trampling; similar conditions had been observed in the mowing trials previously considered in this paper. This effect would be increased by the mass of clippings returned especially in humid weather conditions. The method is not being pursued by the Grasslands Divisions as it apparently produces results of only limited value.

For measuring the potential performance of some species the simple mowing method seems satisfactory so long as the exhaustible soil nutrients removed in the herbage are replaced by artificials.

Both white and red clover strains are measured under mowing at Grasslands Division to test their potential value. Some difficulty has been found at Palmerston North with red clover plots due to the invasion of white clover after the first season, but at Lincoln, Canterbury, where the competition of white clover is not great, the measurements of red clover have been satisfactory. From such trials, only relative yields are used and the nutrients removed (except nitrogen), are replaced by regular applications of fertilizer. As the potash status of the soil is high, this component is not usually replaced during the trial as this not only appears unnecessary but has a definite leaf-burning effect if applied in large quantities.

A useful modification of the mowing technique has been in use lately for the measurement of short lived strains of ryegrass (notably Western Wolths ryegrass). Sown pure, plots of these short-lived strains of ryegrass are mown and replacements of the nutrients removed are made, either by dung and urine collected from elsewhere and the amount necessary calculated from the analyses, or else by a combination of artificial fertilizers. As the trials are for short duration only and the various stock grazing effects would not be of great moment in practice, this system offers scope.

As a means of measuring phosphate response on various soil types, Smallfield (9) has suggested the pure white clover sward under mowing. This is now under trial by Lynch (9) and offers a useful exploratory method for field trial without using the animal. Pure clover swards are fairly difficult to establish and maintain, and because of the low winter growth of this species and its lower total potential production as compared with ryegrasses, it is here suggested that a better proposition would be to use a pure ryegrass sward under mowing. Such a sward can be readily established and maintained if the soil nitrogen is kept up to a *high* level. Variations could easily be made in other limiting factors and some very useful indications of available soil nutrients could be secured. The amounts of artificial fertilizer required would of course be very large for a high production sward, as can be seen from the quantities detailed for the dung and urine equivalents earlier in this paper, or can be calculated from herbage yields and animal retentions of plant nutrients. As the areas required for detailed trial work are small the cost involved is only a very small item in the total expense of the work. Trials are at present in progress at the Grasslands Division to endeavour to find some nitrogenous fertilizer or combination that will prove compatible for continued grass and clover growth at the high levels of pasture production (6).

The Alternate Mowing and Grazing Technique

This method has been discussed fully by Hudson (8) its originator, and later by Lynch (9) who has submitted data on its validity. The criticism to be found is in the question of transference of fertility between treatments by means of the dung and urine of the animals grazing the common enclosure. Mention has already been made in this paper of the large amounts of nutrients so returned and also the movement of the sheep to the headlands, especially at night.

The main evidence of such transference of fertility is that of the actual appearance of the plots during the trials. The botanical work for trials of this technique was carried out by Grasslands Division and it was apparent from detailed examination of the plots that a large amount of transference obviously did take place, and that treatment differences were often masked by the dung and urine effects. In the fertilizer trials it was obvious that the control series produced much more than surrounding farm areas under similar conditions, while the headlands showed the effect of large concentrations of stock droppings. The pasture strains trials conducted at the same time did not show differences of anywhere near the order found in other large scale paddock trials or in single plant studies of the same plant material.

However, Lynch concluded from his statistical examination in comparison with other methods, that this system gave reliable results for fertilizer applications, and that the transference did not take place as

much as was imagined, although he agreed that the differences recorded were appreciably less than those measured under paddock methods.

In a short term trial reported by the author (10) where comparisons were made of the effects of phosphate, using different clover strains, it was found that the responses to the added phosphate as measured under the common enclosure with free grazing, were much lower than those obtained from trials in surrounding paddocks under the same treatments. Similarly measurements made on strain performances gave results differing from paddock trials.

Another comparative trial of four years' duration has just been concluded in Canterbury and the results are now in the course of publication (11). In this trial several strains of ryegrass and seeds mixtures have been under plot test. The relative field performances of these strains were previously fairly well known from other trials and from breeding records.

One series of plots was measured in a randomized block layout under this common-enclosure-open-grazing technique while another duplicate series was measured under the technique of grazing and proportional return to be discussed later in this paper.

The trial has been outstanding in that under the open-grazing system *no significant differences have been recorded between the strains or the mixtures,* while the general run of order of the yields, even though of no significance, has been very jumbled. On the other hand, in the proportional return system, there have been consistent differences of high statistical significance, together with the order of yield and compositions being very consistent with breeding records and other field trials in the district. One is therefore even more doubtful of the validity of the mowing and open grazing as a pasture measurement system.

It is of considerable interest, however, to consider the reason why the open grazing system should give a reasonably accurate picture of phosphate and lime differences and not of measurements on pasture strains. A possible explanation that suggests itself to the author is as follows:—

The amount of CaO taken up by a high producing ryegrass dominant pasture of about 10,000 lb of dry matter per acre is equivalent to about 2-3 cwt carbonate of lime; therefore, even considerable transference of fertility by the dung and urine could not fully mask results of high applications in the lime dressings under trial. With phosphate, the amount taken up per acre would be equivalent to about 4-5 cwt of superphosphate per annum. This amount if transferred could easily mask the response of phosphate applications "out of the bag," except for the fact that in the winter months, the effect of phosphate added as superphosphate appears to be much more effective than phosphate in dung, presumably because of lowered soil bacterial action at that time. Therefore it would be expected that an autumn application of superphosphate would give measurable response for the autumn and winter periods, even though phosphate was being taken off in the dung from this plot and distributed to plots within the enclosure. Similar results would apply with nitrogen and potash, although the masking effect would be much greater because of the very large amounts turned over by the plant and animal for the same pasture growth. It would be expected that the total soil nitrogen would rise over the total set of plots with such a method.

In measuring differences between grass and clover strains on the other hand, the position is much different. In such trials uniform dressings of superphosphate and lime are used, and thus all plots benefit equally in this respect. The large effect of the transference of nitrogen in the urine, however, shows up very markedly where differnt strains of grasses are under test, as the main limitation on extra growth of the grasses is (largely) from nitrogen. Thus one would expect good strains to suffer and poorer ones to benefit.

An extreme case would be where a pure clover sward is being compared with one of pure grass. In this case the transfer of dung and urine, derived from a high initial growth of clover built up from added phosphate, would give the grass a great advantage over the clover, whereas the urine from the grass would not be of much value to the clover. Thus the grass plots benefit very greatly at the expense of the clovers; similar conditions apply with such cases as combinations of poor grass with good clovers and vice versa, and thus only very wide differences of species, involving mainly differences of persistency, would be picked up in the measurements. For instance, if a strong ryegrass was sown with good clover, and compared with poor ryegrass and poor clover, the fertility transferred from the good plot to the poor plot would have little effect on the poor plot itself, as the species there could not respond to that extra fertility; although of course, the total yield of the good plot would be considerably reduced.

Paddock Trials

By using areas sufficiently large for grazing with stock, the conditions of actual field practice can be approached much more easily than with normal plot techniques. Stock grazing can be measured and adjusted both by using one class of stock at different intensities, and also by combinations of stock.

There are, however, a few points of difficulty in using paddocks for comparative work which should be considered. First is the point that it is usually more difficult to find large enough areas which are sufficiently even in topography and fertility, to give fair comparative conditions without a large amount of replication. This soon leads into very high costs; also, it is quite often undesirable to have trials spread over several different types of soil or topography. It becomes largely a question of deciding what is the minimum paddock size upon which stock can be satisfactorily grazed. At Grasslands Division where sheep are used almost entirely, the normal paddock size adopted is about one-tenth of an acre, rectangular in shape. Fairly uniform swards can be grown although there is often considerable variation developed through stock manure, while trampling around the gates leads to some error. This increases in importance as the size of the paddock becomes less.

The most satisfactory paddock system in use is that of the self-contained block of paddocks, each carrying its own set of grazing stock which remain permanetly on that block and with the separate paddocks of each block arranged in a randomized layout. Grazing is carried out either by continuously stocking each member paddock of the blocks, or else on the rotational system. Continuous grazing gives a theoretically sound basis for treating each paddock of a block as a true replication, but there is the obvious defect of continuous grazing as a method of getting the best production from the pasture. Rotational grazing within each treatment has the advantage that it is the proven management

method for getting the best out of each treatment, but there is the argument of whether each separate paddock does in fact constitute a replication. The first point is that the paddocks are all grazed at different times because of the rotation adopted. For long term comparisons it is generally agreed that such grazing difference effects will cancel out, and from this point of view each paddock can be treated as a replication. On the other hand the movement of stock from paddock to paddock with the carryover of soil fertility in their dung and urine will, no doubt, show that each paddock is not a true replication in the full sense of the term.

The result of the carryover of dung and urine in the rotational grazing is a general levelling of soil fertility within the block, as mentioned earlier. There is a 1 to 3 day carryover of dung and urine with animals, and thus if they rotate from a paddock where they had plenty of feed, to one where it is poorer in growth, then this second paddock will receive back some extra dung and urine, which will then help to level the early difference in growth.

An instance of this can be seen from Table II in which are set out the yields for the 10 paddocks of such a self-contained rotationally grazed block at Palmerston North, for the first six months after sowing down, and those for two years later.

Table II. Change in Yields of Herbage within a Self-contained Rotational Grazing Block at Palmerston North over a 2-Year Period

Paddock No.	Dry Matter Yield per Acre (lb.).	
	First 6 Months after Sowing March-September, 1946.	2 Years later. 6 Months January-July, 1948.
10	3911	3428
11	3848	3895
12	3774	3722
13	3074	3257
14	1817	3890
15	2032	3459
16	2263	3860
17	2687	3883
18	2067	3953
19	1863	4161

The above levelling-out process is quite typical of blocks of paddocks where the general soil conditions are reasonably uniform. With wider extremes of original soil type the levelling process does not always continue to such a stage on account of the variability in drying-out, etc. in different seasons. However, it will be appreciated that such a levelling out within blocks of paddocks is a very satisfactory method of reducing experimental error due to soil differences, and the final practical result is much more satisfactory than where large internal differences occur on each treatment block. However, insofar as the independent measurements on each paddock of the block contain the many errors associated with the work, it is probably valid to treat each paddock as a replication for that particular soil type on which the trial is being conducted. In practice it is usual to seek as *even* a piece of land as possible for a trial; rotational grazing can be viewed as a valuable aid in this respect.

As an additional means of keeping the paddock grazing and return of dung and urine *even*, it is usual on all blocks of paddocks at Grasslands Division to surround the measurement areas with small "decoy" areas. Animals are grazed on these at the same time as on the main

blocks. This is because of the gregarious nature of sheep which always leads them to congregate as near together as possible with the result that the outside areas of a block always tend to receive much less than their full share of dung and urine. The falling off in production and a reversion to low fertility species is the usual result of such treatment, which apart from the total loss of production also results in a much more difficult sampling and measurement programme on these outside paddocks.

Typical of the growth in an outside paddock of a series without surrounding "decoy" areas are the data shown in Table III.

Yield and botanical compositions were recorded at an equal distance in from each side of two sets of adjoining paddocks, one of these being on the end of the series near a road frontage. It is obvious that the greater variability within these outside areas makes it much more difficult to judge the real effects of their particular treatments compared with the much more even sets. As a matter of interest two additional sets of data from farm paddocks are included. In both these cases the lower producing sides of the paddocks are on a main highway frontage whilst on the other side are shelter belts, which naturally assist in the "draw" of grazing stock to that part of the paddocks.

The measurements shown are the simple means of a number of cuts made within each sampling area on 15th October, 1948. The separate data are not shown in detail but there was actually very little replication difference, and thus the mean figures as shown give a fair picture of the position as at the date of sampling. Ground cover analysis made at the same time on the two Massey College paddocks examined, showed that the side of the paddock nearest the road had a cover as follows: Ryegrass, 18 per cent; browntop, 27 per cent; sweet vernal, 15 per cent; dogstail, 2 per cent; Yorkshire fog, 1 per cent; white clover, 15 per cent; suckling clover, 14 per cent; weeds, 9 per cent; and bare ground, 2 per cent. The other side of this paddock was markedly different and showed the following result: Ryegrass, 65 per cent; white clover, 30 per cent; sweet vernal, 4 per cent; and bare ground, 1 per cent.

Similar striking differences can be seen on hill country pastures, due to the very clear definition of zones of growth induced by the grazing stock. Close examination shows the stair-like structure of a typical grazed hillside, this having developed from animal tracking along the contours. Most of the dung and urine naturally falls on the "treads" and these carry pasture very different from that which develops on the "riser" areas between. These latter are grazed by the animals standing on the tracks but do not receive any return of fertility. Neither do they obtain the effects of the trampling and "hoof cultivation" which are confined, perhaps too much, to the animal tracks and "camps." It is usually on these unmanured "riser" areas, close grazed and depleted in fertility, that growth of fern, scrub, and other weeds commences as well as surface erosion.

The effect of animals "camping" on ridges and other dry or protected areas can be seen in Table IV, in which are shown yields of pasture on hill country near Palmerston North. Measurements were made by use of replicated protecting cages and by hand clippers, the cages being shifted after each cut. Three different areas were measured to obtain data on the extreme range of pasture growth found on this

class of country. One paddock of 50 acres had been topdressed with phosphate and oversown with grasses and clovers (6). This is compared with the adjoining untreated paddock, both areas being under sheep and cattle grazing. The other area is a fairly sheltered place on the treated paddock, where the animals "camp" at night and in very severe weather.

TABLE III. INTRA-PADDOCK VARIABILITY INDUCED BY STOCK MOVEMENTS FROM ONE SIDE OF AREAS TO THE OTHER (SAMPLING DATE 15/10/48)

Situation of Paddocks and Sampling Areas.	Relative Dry Matter Yields at Sampling Date.	Botanical Composition—Percentage of Dry Matter.											
		Ryegrass	Cocksfoot	Timothy	Dogstail	Browntop	Sweet Vernal	*Poa trivialis*	*Poa annua*	Other Grasses	White Clover	Suckling Clover	Other species
Grasslands Division—Timothy Types.													
1. Outside paddock of block without decoy.													
(a) Outer side	100	21	—	39	—	—	—	3	19	—	22	—	5
(b) Inner side	427	45	—	11	—	—	—	Tr*	20	—	23	—	1
2. Paddock next in to outside paddock above													
(a) Outer side	100	13	—	46	—	—	—	Tr.	7	1	33	—	Tr.
(b) Inner side	104	12	—	53	—	Tr.	—	—	8	—	26	—	1
Massey College—Fertiliser Trial.													
1. Outside paddock of block without decoy area.													
(a) Outer side	100	63	Tr.	—	Tr.	18	8	—	Tr.	Tr.	7	1	3
(b) Inner side	331	90	—	—	—	1	Tr.	—	Tr.	Tr.	8	—	1
2. Paddock next in to outside paddock above													
(a) Outer side	100	93	1	—	—	—	Tr.	1	—	—	5	—	Tr.
(b) Inner side	103	94	—	—	—	—	1	1	Tr.	Tr.	4	—	Tr.
Karere—Ryegrass and Clover.													
Paddock next to roadway.													
(a) Nearest road	100	26	—	—	3	—	13	1	—	Tr.	54	1	2
(b) Furthest side away	263	38	—	—	Tr.	Tr.	Tr.	12	Tr.	1	48	Tr.	1
Bunnythorpe—Perennial Ryegrass and White Clover													
(a) Side nearest road	100	73	—	—	1	12	Tr.	3	2	1	2	Tr.	6
(b) Side furthest away	199	81	—	—	—	—	1	12	2	—	1	—	3

* Tr. = trace.

Table IV. Difference in Yield of Hill Country Pasture Near Palmerston North, Due to Fertiliser and Seed Oversowing, and to Transference of Fertility by the Grazing Animal. Period, June, 1947-June, 1948

Treatment.	Total Dry Matter per acre.	Crude Protein.		Botanical Yield of Dry Matter.				Botanical Percentage of Dry Matter.			
		Total. (lb.)	Percentage of Dry Matter.	Rye-grass.	Other Grasses.	Clovers.	Other Species.	Rye-grass.	Other Grasses.	Clovers.	Other Species.
1. Normal grazing—no treatment.	2909	327	11·2	382	1861	135	531	13	64	5	18
2. Normal grazing—superphosphate plus oversowing with clovers.	5129	750	14·6	960	3141	892	136	19	61	17	3
3. Same as 2, but area of stock concentration.	9338	1700	18·2	4073	4129	534	602	44	44	6	6

Thus both from the yield and herbage compositions and from the ground cover by the species, it can be seen that there has been a considerable movement of fertility across the paddocks. The need for and the value of "decoy" areas is clearly seen from the data, the outer paddocks of these series of course being considered as acting as such for this purpose. Although the "decoy" system is satisfactory for experimental work it is of course impracticable for general use. On the farm, however, adjustments can be made in the application of fertilizers, and in the placing of shelter belts of trees, gateways, and watering troughs so that the effects of these act as a counter-draw to even up the soil fertility movement by the grazing stock.

This fertility transference by stock is a disadvantage when using sets of paddocks to compare fertiliser or plant differences, and where sets of paddocks are grazed down periodically. If for any reason one treatment is less palatable than others, then more animals have to be used to get the herbage eaten in the same time as on the more palatable treatments. It thus occurs usually that there is more dung and urine returned to the unpalatable treatment per pound of dry matter eaten, than on the others, and so these unpalatable pastures gain an advantage from the soil fertility point of view. Such a fact does not happen on self-contained areas, of course, as the dung and urine dropped on the block does originally always come from that block, and not from outside sources as can happen on the non-self-contained sets of paddocks. It is a very strong argument in favour of the self-contained grazing block and one which has repeatedly been shown on measurements at Grasslands Division.

Estimation of Paddock Yields

Several methods of estimation of herbage consumption by the animals have been tried. Mown strips before and after grazing have been tried and discontinued because of subsequent damage by the stock and also the difficulty of equating such measurements to animal ingestions. The current and uniformly accepted "best" method is to use protecting cages and to cut such areas at the end of each grazing. Sufficient numbers of frames are used to overcome sampling errors due to non-uniformity within the paddock. Some workers use the mower to cut the herbage, after a trimming cut at placing time, and estimate the consumption by difference in weights. Some too, prefer to place the frames purely at random within the area, working on the principle of non-personal element and also the fact that large numbers of replicated cuts will overcome most of the errors of intra-paddock differences.

The system in use by the writer is somewhat different in principle in that sufficient frames are used to overcome the intra-paddock differences provided these frames are carefuly placed at each time of grazing. This involves a personal element in the placing of the frames, but this may be justified on the score of the economy of frame numbers. Also the cutting of the frames is carried out by using hand shears (12) or by plucking the herbage by hand. The whole aim is to copy the irregular defoliation pattern made by the grazing animals. Again this can be criticized on the score of the possibility of human bias in the cutting. In practice it is found that where large numbers of paddocks are under trial, there is no bias on the part of the field technicians doing the cutting; the only immediate aim is to cut or pluck the enclosed frame area so that no difference can be seen between the sampling area and the total grazed area. The method has also the advantage that a very clean sample can be obtained for botanical and chemical work.

It is only reasonable to suppose that small differences between the grazing and the sampling heights of cutting will iron themselves out over a period, but there is the possibility of an overall difference due to the probable less efficient utilization by the grazing animal. In trials at Grasslands Division a constant check is made on the cutting heights, by inspection by independent observers, and also as many checks as possible are made by means of comparison with calculated feeding values and those made under actual controlled condition using similar feed material. Opportunity has also occurred to check feed consumption estimates with the total amounts of excreted nutrients using mature animals.

In all these checks very good agreement has been obtained with the checks against the excreted dung constituents; some difficulty has occurred with urine nitrogen on account of losses of this material during storage in the field (3).

Working at Ruakura, Wallace (13) has recently adopted this hand-cutting and/or plucking technique as a means of estimating herbage consumption by grazing cows. His results to date show very good agreement with data from parallel digestion trials and calculation from dung collections of the animals grazing.

The above background of experience gives sufficient basis to recommend this system of placed frames and hand cutting as a good method so long as a very reliable team of workers is available, and also *constant* check is made within the field and with other measurements.

Proportional Return Plot Technique

This technique was designed by the writer as a means of approximating in a plot test, the conditions obtaining on a self-contained block of paddocks under rotational grazing. Details of the technique have been published by the writer (10) and Lynch has given (9) an outline as well as some comments on its validity as a technique.

Briefly, the system is as follows:—

(a) Plots are set out in a common enclosure on a suitable randomized block layout.

(b) When ready for grazing mower cuts are taken for weight and sampling; the cut herbage is then put back on the mown strip.

(c) Sheep harnessed for dung and urine collection are grazed on the paddock until such time as the rest of the herbage is eaten down to the height of the mown strip.

(d) The dung and urine are collected, and placed in large drums.

(e) At the end of the grazing the dung and urine are returned to the plots in proportion to the dry matter yields of the herbage from each treatment. Each replication of each treatment receives back equal amounts, i.e. the total amount to go back to each treatment as a whole is divided equally between the replication of that treatment, irrespective of he yield variability between the replications.

(f) After grazing, any small irregularities due to differences in palatability etc. are trimmed up by the mower, and thus all plots start from a common level for the next growth period. There are several points which should be considered in connection with the use of this technique.

(1) The collection of the total dung and urine and return of it to the treatments in proportion to the plot yield avoids fertility transference so far as total weight of dung and urine is concerned, but may be wrong considering the composition of the dung and urine constituents. In such cases, of course, any plot technique under grazing would be equally faulty, but this fact does not operate in favour of the collection technique. For most purposes, however, especially with species and strains trials, the composition of the dung and urine is sufficiently constant not to upset the trial. It does, however, tend to give more conservative results, in favour of lower-producing as compared with the higher producing plots, because they receive higher quality dung and urine than is represented by the herbage growth on those plots. However, if necessary, this can be adjusted by returning the dung and urine in proportion to some yield of nutrient rather than to total dry matter, e.g. Crude Protein.

(2) Losses of nitrogen as ammonia from urine and dung collected and stored, can be quite high, and thus with such a system an overall total loss of fertility is possible. This can be especially high in hot weather (up to 30 per cent of total nitrogen) and is difficult to provide against in normal field practice. These losses should, of course, be checked against normal losses in grazing from the excretions, before a full evaluation can be made.

(3) The returning of equal amounts of each replicate of a treatment may be criticized on statistical grounds. However, as pointed out in considering paddock trials, this general levelling-out of fertility is what actually takes place in practice under rotational grazing, and so one feels that if such grazed blocks are valid then it is justifiable to apply such reasoning to plot techniques.

(4) With the method as described, the measured yields will be less than the total actual growth because of the non-measured amounts during time of grazing. In practice the importance of this varies with the trial itself, but if essential, total yields could be obtained by using paired sets of plots which are measured at different times as in the "Hudson" mowing and grazing technique, or else a close approximation can be made by calculating from the measurements as made, the proportion for the times under actual grazing.

(5) The method of mixing together and returning the dung and urine has caused some difficulty by its failure to produce exactly the same botanical composition and yields obtained under grazing. This has been especially so at Palmerston North and has been noted over the past five year period, whereas in Canterbury the results secured on similar trials have been much more satisfactory.

The main difficulty appears to hinge around the growth of the white clover relative to that of the associated grasses. At Palmerston North this is much more vigorous than in Canterbury with the more extreme growth conditions of the latter area. Comparative yields of pure stands of pedigree New Zealand white clover grown to best advantage at Palmerston North and at Lincoln are shown in Table V, the data for which has been taken from trials in progress by Gorman (14) and Thurston (15).

TABLE V. AVERAGE TOTAL AND SEASONAL PRODUCTIONS OF PEDIGREE NEW ZEALAND WHITE CLOVER GROWN IN PURE STANDS TO BEST ADVANTAGE AT PALMERSTON NORTH AND AT LINCOLN

Locality.	Total Annual Production of Dry Matter per acre, (lb.).	Percentage of Annual Production.			
		Spring Sept.-Nov.	Summer Dec.-Feb.	Autumn March-May.	Winter June-August.
Palmerston Nth.	10,000	40	39	13	8
Lincoln	3,700	14	60	21	5

In plot trials at Palmerston North comparing strains of grasses sown with white clover, there has been the tendency for the grasses to become choked by the clover in all the plots, especially following the summer period. Consequently the comparisons between the grass strains has not been as clear-cut as in comparative paddock trials. Many reasons were discussed and different combinations of mowing and grazing were tried out. None of these seemed to produce the desired result, and finally attention was paid to the method of returning the dung and urine. When considered in detail the difference between the way the animal returns dung and urine, and the method adopted of mixing it all up and putting it back evenly with a watering can, does offer a marked contrast. Measurements on sheep urination show that the average amount passed by a well-fed animal is about 150 ml. each time. This as before stated falls on an area of approximately 36 sq. in., and thus on this small area there is an amount of urine dropped equivalent to a dressing of over one ton of sulphate of ammonia and about 19 cwt of 30 per cent potash salts per acre. Such high concentrations of these nutrients will give the clover a very severe check and in frosty weather will also check the grass and result in too severe scald in hot dry weather. However, the normal heavy dose of urine quickly gives the grass a chance to grow vigorously and so to become dominant over the clover. With *even* spreading back of the same amount of dung and urine over the sward the concentrations per unit area are much lower, and the grass does not gain such a quick advantage over the clover. This is due partly to the lack of the set back to the clover, as well as the lesser amount of readily available nitrogen at that spot.

In the trials at Lincoln on the other hand, this result has not been so noticeable because of the fact that due to the greater summer heat and winter cold the clover dies down quite markedly. Consequently, the grass holds its dominance much better.

An extreme instance of the type of variation occurring at Palmerston North between paddocks under grazing, and comparable plots under the proportional return technique when the dung and urine were mixed and spread back evenly over the plot is shown in Table VI. Only differences in botanical composition are real as the total yields are not directly comparable, due to the amount not recorded during the grazing periods on the plots, and also to some differences in the period cuts between the paddocks and the plots.

It will be appreciated that such a variation in composition must affect the results within the plot series considerably. Where, for instance, it is a question of measuring phosphate differences, such a lowered grass content will affect greatly the amount of phosphate response in the

Table VI. Botanical Composition as Percentage of Dry Matter and Herbage Yields of Same Pastures under Different Measurement Systems at Palmerston North

	Rotational Grazed Paddocks.			Plots under Proportional Return.			Dry Matter per Acre.	
	Grass.	Clover.	O.S.	Grass.	Clover.	O.S.	Paddock.	Plots.
	(%)	(%)	(%)	(%)	(%)	(%)	(lb.)	(lb.)
Spring 1947	76	23	1	57	41	2	3689	3617
Summer 1948	44	54	1	23	74	3	3309	2885
Autumn 1948	52	47	—	32	68	Trace	2086	1766
Winter 1948	72	27	1	71	29	Trace	1807	1845

winter to added phosphate, on account of the much greater potential growth of grass relative to the clovers in that period.

The method now adopted is to collect the urine and dung and put these back separately, the urine being poured back as soon as possible to avoid the nitrogen losses, and the dung applied after being dried and ground so that there is no necessity to break up the "pats" which previously caused uneven grazing and a consequent greater difficulty of measurement.

So far, the results using this modification appear to be quite satisfactory. Another series of plots has been under test for the past year, and results to date, although not conclusive, give a strong basis for believing that future work will be quite satisfactory.

For some months the practice was followed of putting the urine back in "doses" irregularly over the plots. This is now giving results similar to those found in the grazing paddock, although it has introduced the need for greater sampling sizes both in herbage and in soil measurements. In addition, a considerable programme of work is being followed to obtain further data on the amounts and composition of the urine passed, and the fate of the constituents when it falls to the ground in such high concentrations at different times of the year. As an example of the value of the "proportional return" technique in measuring the performance of bred strains of ryegrass in comparison with the "Hudson" mowing and grazing technique, the following results can be quoted from a recent trial in Canterbury (11) where, as previously stated, the difficulty of the clover-grass relationship did not apply. In this trial there were six different mixtures of grass strains with the same white clover common to all. Layout of the trial was on a randomized block system using three replications in each enclosed area. Table VII shows the comparative results using the two techniques under discussion.

In this trial the grazing times for both series were exactly the same and the data are strictly comparable, treatment numbers being the same for both sets of plots. As can be seen, any real differences in strain performance are masked in the open-grazing method by the errors induced by the transference of fertility within the enclosure. This was quite apparent through the course of the trial. On the other hand clear-cut differences were shown when using the proportional return technique. A feature of the data not shown in the Table was the very low Block variance using the proportional return technique, which contrasted markedly with the position in the other paddock. On the latter there was

a clearly defined transference from one side of the paddock to the other. This was brought about by factors similar to those mentioned in the discussion of this aspect earlier in this paper and was reflected in marked block variability both in yields as well as in botanical composition.

There are several other trials in progress at Grasslands Division and the sub-stations at Lincoln and Gore, using this system. On all these, results to date are satisfactory but a constant check is being made with a view to finding and correcting any weaknesses other than these mentioned. In addition, work is continuing on the search for a mixture of fertilizers which will adequately replace dung and urine.

Botanical Composition

The full interpretation of results from pasture trials calls for a sound basis for the measurement of botanical changes. In trials at Grasslands Division two main systems are in use. For the determination of the percentage of ground covered by species, although other quadrat

TABLE VII. COMPARATIVE YIELDS AND ORDER OF DIFFERENCES IN A TRIAL OF DIFFERENT STRAINS OF RYEGRASS AT LINCOLN USING TWO TECHNIQUES OF PLOT MEASUREMENT. (DRY MATTER YIELDS TO NEAREST 100 LB. PER ACRE FOR THE TOTAL 4-YEAR PERIOD OF THE TRIAL)

Open Grazing.		Proportional Return of Dung and Urine.	
Plot No.	Relative Dry Matter Yields. (lb.)	Plot No.	Relative Dry Matter Yields. (lb.)
2	113	3	174
3	104	6	172
5	101	5	160
1	100	2	153
6	100	4	151
4	91	7	143
7	89	8	137
8	86	1	100
F. Value	2·4	F. Value	19·3 XX
Signif. Diff. at 5% level	No Signif. Diff.	Signif. Diff. at 5% level	11·6

methods have been tried, the Point Analysis system designed by Levy (16) is still the favourite because it gives the most objective and definite measurement of this aspect of pasture growth.

For the determination of species composition, the method of direct herbage dissection into component species is used almost exclusively. This system has been fully described by Davies and others (17). Work at Grasslands Division by the writer has been directed along the lines of adding precision to sampling technique and of oven-drying the separated species down to the same dry matter content as the samples used for yield and chemical compositions. This latter adjustment is necessary because of the different dry matter contents of the various species, and the differential drying out between species during the actual sample dissection process.

In his original work Levy endeavoured to use his Point Analysis method as a means of estimating percentage productivity of the component species of the sward. Since then, other workers have followed

the same lines of thought and either by adjustment of the angle of strike of the pointing pins and/or by constants for each species (18), have searched for and claimed success by this method. Much work has been done on the sampling sizes for pastures of different composition and variability (19) with the nett result that the number of points around about 400 per association appears to be satisfactory for at least the main constituents. Although no statistical work on this subject has been carried out at Grasslands Division, this optimum sample size is approximately that which the workers at this Station have found by empirical methods.

Table VIII. Leaf Area and Weight of Some Leaves of Common Pasture Plants. Palmerston North (June, 1948)

Species.	No. of Leaves.	Total Area (sq. in.)	Total Green Weight. (g)	Total Dry Weight. (g.)	Green Weight per sq. in. (g.)	Dry Weight per sq. in. (g.)
Perennial ryegrass	22	15	2·4	0·4	0·16	0·027
Cocksfoot	13	45	3·9	0·8	0·14	0·024
Prairie grass	12	56	7·9	1·3	0·09	0·018
White clover (Leaves)	25	60	6·1	1·1	0·10	0·018

To the writer it seems fallacious to endeavour to equate the results secured by the Point method to those secured by herbage weight analyses. It is very apparent in a sward that some plants have a much greater ground-covering ability than others because of their growth habits; moreover, there are considerable differences in the ratios of leaf area to dry weight. For instance, on comparing crested dogstail and perennial ryegrass, it is found that the leaves of the former branch off the stem almost at right angles, while those of the latter come off at an agle nearer to 45°. All that is measurable by the Point method is the vertical projection of the leaves on to the ground surface. An extreme difference is that between flatweeds or clover leaves, and leaves of such plants as Chewings fescue or the rush group. Examples of the second main point of difficulty are seen in Table VIII in which are set out a few measurements on leaves of differing character.

For these measurements several random leaves of the above plants were weighed fresh and then clamped between two sheets of glass. This was then used to cover a sheet of photographic paper then exposed to light. The leaves were then dried and weighed, and the areas covered were determined by use of a planimeter on the developed paper.

It is obvious that with two such variable factors operating, any workable conversion from ground cover to weight composition is unlikely to be found.

As a means of obtaining a good numerical picture of a pasture sward, the combination of the results secured by the Point Analysis system with those from actual weight percentages is of great value. Table IX shows a comparison of two pastures, one with Kentish and the other with New Zealand certified white clover in a common mixture of grasses. The data shown are for one sampling only.

Table IX. Botanical Composition of Two Pasture Swards at Palmerston North Sown with Different White Clover Types

Measurement Basis.	Variable (clover).	Botanical Composition. Ryegrass. (%)	White Clover. (%)	Cocksfoot. (%)	Other Species. (%)	Bare Ground. (%)
Point Analysis % of ground covered by species.	Kentish White	40	40	8	12	7
	N.Z. White	46	43	4	6	6
Percentage composition of dry matter of components herbage sample cut to ground level.	Kentish White	86	9	4	1	
	N.Z. White	54	34	7	5	

From these data it can be clearly seen that although the Kentish white clover was covering 40 per cent of the ground it was directly contributing very little to the total herbage yield. On the other hand the much more erect growing New Zealand type similarly covered 40 per cent of the ground but contributed considerably to the total yield from this plot. It will be agreed that two complete sets of such botanical measurements together with the total yields will enable a very clear picture of the swards to be presented.

Herbage Dissection

In testing the accuracy of the herbage dissection method of analysis, attention must be given to the three steps in the process. These are as follows:—

(1) The identification of the species by means of leaf and stem characters alone.

(2) Testing the adequacy of the sample of mixed herbage to be dissected into its component species.

(3) Testing the adequacy of the sample as being truly representative of the pasture under examination.

Considering these in sequence it may appear a simple matter to separate species on the basis of leaf character. In actual practice it is found to be a fairly tedious and exacting task, especially when the pieces of herbage are very small or at all wilted. For this reason it is essential to keep the samples fresh by using waterproof bags; in addition, they must be kept in a refrigerator until actually dissected. It is an advantage to take only a small amount on to the table out of the bag at one time so that the minimum of wilting takes place.

It has been found that girls become the best assistants on this dissection work, although at Grasslands Division it is a very useful training ground for all assistants doing pasture field work. Identification is based on the leaf characters of hairiness, venation, shape, shininess and colour, and character of ligule and leaf bud.

The analysis routine followed in the dissection laboratory is as follows:—

(a) The sample is thoroughly mixed on a table. Large pieces of herbage are broken up and mixed with the smaller pieces. Total herbage

is then sub-sampled by quartering down to the approximate quantity decided upon after examination of the complexity of the sample itself. This sub-sample is then weighed on a coarse balance and placed in a waterproof bag in the refrigerator set at 10°c. This temperature keeps the herbage fresh without freezing or cytolysis of the leaves when removed.

(b) For dissection, the sample is placed on the analysis table and a small amount taken out of the bag and separated into heaps. Care has to be taken to get a good light without direct sunlight or too much heat as this quickly wilts the sample and makes identification difficult. The tables in use are covered with brown leatherette as this avoids glare while giving a good comparative light.

(c) The separations are placed in an electric oven on trays and dried out at 80°c. for approximately 16 hours. These are then weighed on a laboratory balance and the percentage composition determined on this dry basis. The total dry matter of the sample is a check against the dry matter percentage as determined on a separate sample used for chemical composition of the complete herbage. If desired, the separated pure species are then stored and used for chemical determination on the species themselves.

(d) Accuracy of analysis is checked by duplicate samples independently taken and dissected. The standard aimed at is 5 per cent of the means on percentages over 50 per cent and about 20 per cent for the minor constituents. In actual practice seasonal compositions are used for main comparisons and as these usually include several samplings within each season, it is found that sampling errors tend to be cancelled out, so that the standard set does not have to be unduly high. However, any standard of accuracy desired can be achieved by the analysis of several samples of different sizes, and the statistical calculation of the error variance. Several years ago the author obtained a large quantity of data on this question of sample size, but unfortunately it was all lost in the fire which destroyed Grasslands headquarters. However, the conclusion arrived at was that the average sample size required for reasonable accuracy was 25 g. of fresh material for short herbage (up to 1 in.-2 in.) and up to 500 g. for very long herbage (12 in.-24 in. hay crop). Greater quantities are necessary for very complex samples than for simple associations. It reduces the sample size considerably if care is taken to cut up all outside pieces of herbage in the sample before mixing. On the other hand, the sample size should not be made too large, as errors develop from the fatigue of the workers. It is much better to do several small samples and taken the simple mean, than to dissect out one large sample. After a year or so the work becomes largely an art and very considerable accuracy is gained by the girls in deciding on the size of the samples to be taken for the different types of herbage. Continual check is made by duplicate samples. In Table X is shown a specimen analysis of a mixed sample into its simple components. Several check samples of different weight were taken out of the mixed herbage after a preliminary opinion was given by the analysts that 50 g. of this particular sample was sufficient and that this amount would normally be taken for such a sample.

The herbage used for these analyses was taken from part of the amount left over after taking the samples for the analyses shown in Table XI. Although the materials dissected were not from exactly the same population, the results shown in these two tables are complementary.

TABLE X. VARIABILITY BETWEEN ANALYSES OF SAMPLES OF DIFFERENT SIZES. HERBAGE DISSECTION OF MIXED HERBAGE FROM PASTURE 3-4 IN. IN HEIGHT (PALMERSTON NORTH, JULY, 1948)

Sample Size.	No.	Percentage of Total Dry Weight.		
		Ryegrass.	Clovers.	Other Species.
25 g. Green Weight	1	60	36	4
	2	75	21	4
	3	66	31	3
	4	65	31	4
	5	60	36	4
	6	59	38	3
	Mean	64	32	3
50 g. Green Weight	1	68	29	3
	2	60	36	4
	3	63	32	5
	4	70	27	3
	Mean	65	31	4
75 g. Green Weight	1	65	30	5
	2	68	28	4
	3	63	32	5
	Mean	65	30	5

It can be seen that the accuracy of the analysis increases with the weight taken. This can also be calculated from the variance in the 25-gram samples. In practice, however, at Grasslands Division it would be impracticable to examine more than 50 g. of such a sample on account of the large number of samples being handled, and the usual staff difficulties. Also, this sample represents one of the easiest types to dissect, being of simple composition and with the herbage in an easily identifiable condition. The more mixed samples from low fertility swards present greater difficulties and the standard of accuracy achieved is not usually as high as shown above.

(e) Having achieved accuracy in the laboratory analyses it is then possible to test the accuracy of the field sampling. No difficulty arises on the plot series as the areas mown are always considered as being fully representative of the plots themselves. The matter is not so simple with paddocks as considerable variance is found in nearly every enclosure under grazing. This is due to natural soil variations, to those resulting from induced differences due to grazing, dung and urine, and to light and shade variations within the enclosed area. In addition, because of different seasonal growths of the species of the sward, it is quite usual that a pasture which is a fairly even sward of a single dominant species at one time, will be a very mixed and variable association at some other season. It is thus very difficult to fix on any static system of sampling for a paddock. Each sampling must be individually checked. Two systems of paddock sampling are followed by the writer. If a simple botanical or chemical composition of a sward *as it stands* is desired, the area is divided by an evenly spaced grid and then at each intersection point of the grid a small area is cut to ground level with hand shears. These small areas are usually about 36 sq. in., and the herbage from the cuts are bulked into a bag so that at the end of the sampling this total amount is representative of the whole area. It is important to cut equal

areas at every point—the usual tendency is to cut larger areas at the low growing points to secure a sample of reasonable size. This total sample represents a certain number of cuts. Normally four samples of each size are taken and the numbers of cuts for each usually ranges from 16 up to 256, the steps being varied according to the square of a simple multiple of the square root of the starting number. Theoretically this should give a corresponding drop in the standard deviation, and from the standard of accuracy desired can be calculated the necessary number of cuts. In practice this complicated procedure is not followed because of the large amount of work in the analyses; the actual procedure is to take an extreme range of cuts and decide on the acceptable number by inspection. This standard is then maintained and the number of cuts adjusted after inspection at each sampling. For the relatively uniform swards used for the detailed work at Grasslands Division it has been found that the number of cuts will vary between 40 and 80, but on some much more variable pastures in other localities it has been necessary to take numbers of cuts up to 400 per paddock.

The difficulty of this system of overall sampling of a paddock is that it does not give a measure of the herbage eaten by the grazing animal, although this can be achieved by sampling before and after grazing, and then calculating the differences in herbage.

An alternative to this double sampling is to use the herbage enclosed in the frames used for estimating dry matter yields. After the paddock has been grazed, the herbage in the enclosures is cut or hand-plucked down to the height of grazing, and then weighed for yield and sampled for dry matter, and chemical and botanical compositions. It is important to note that this hand-cutting gives a much cleaner sample for chemical work, and a much more acceptable sample for species separation than is produced by mowing. Mowing samples are usually chopped up into much smaller pieces and quite often include quite a large amount of earthworm casts and faeces. In addition, the use of hand shears has enabled measurement work to be carried out on steep hill country in studies of pasture cover and soil erosion and on other paddocks with difficult access and uneven ground surface (6).

Illustrative of the accuracy that can be achieved in a fairly uniform pasture are the results of a recent sampling of a small paddock at Grasslands Division. For this investigation, the area was first sampled at 12 points evenly spaced to show the variability existing. This variability could be seen and was composed largely of a better overall grass growth at one end of the rectangular paddock, with a general falling off towards the other end. To overcome this difficulty it would be necessary to take a fairly large number of cuts evenly spaced over the paddock. In Table XI are shown the comparison between samples of 4, 16 and 64 cuts while in addition are the analyses of the herbage from the areas protected from grazing for the purpose of obtaining pasture yields. These enclosing frames had been carefully placed, one at each end, in order to get as near as possible to a representative sample of the whole paddock, when the two enclosed areas were considered together.

The amounts of herbage analysed were 75 g. of fresh material in each case as this was the maximum amount which could be handled by the staff. From Table X it would appear that a little more should have been taken to ensure full accuracy but the results obtained are quite satisfactory for the purpose.

TABLE XI. INTRA-PADDOCK VARIABILITY ON A SMALL EXPERIMENTAL AREA AT PALMERSTON NORTH, AND THE COMPARATIVE EFFICIENCY OF SAMPLING BY DIFFERENT NUMBERS OF EVENLY SPACED CUT AREAS (EACH OF 36 SQ. IN.) OVER THE PADDOCK. (BOTANICAL COMPOSITION ON A DRY-WEIGHT BASIS OF SAMPLES OF 75 G. FRESH MATERIAL)

Sampling System.	No. of Cuts.	Sub. Sample No.	Botanical Composition of. Ryegrass.	Clovers.	Other Species.
1. Individual analyses of cuts evenly spaced over the paddock.	Single cut	1	84	14	2
		2	79	20	1
		3	71	21	8
		4	71	23	6
		5	70	29	1
		6	66	31	3
		7	64	30	6
		8	63	36	1
		9	60	39	1
		10	58	41	1
		11	57	41	2
		12	44	50	6
		Mean	66	31	3
2. Analysis of samples from different numbers of evenly spaced cuts within the paddock.	4	1	50	43	7
		2	67	25	8
		3	58	38	4
		4	78	20	2
		Mean	63	31	5
	16	1	67	29	4
		2	74	23	3
		3	70	25	5
		4	69	27	4
		Mean	70	26	4
	64	1	68	30	2
		2	73	20	7
		3	68	31	1
		Mean	69	27	3
Analysis of samples from 2 enclosures each 10 ft. by 4 ft. carefully placed to obtain a representative sample of the paddock.	Frame 1	1	67	27	6
		2	63	29	8
		Mean	65	28	7
	Frame 2	1	76	22	2
		2	82	16	2
		Mean	79	19	2
	Mean of Frames 1 and 2 from above data		72	23	5
	Herbage of Frames 1 and 2 mixed together	1	69	24	7
		2	74	21	3
		Mean	71	22	5

In the table the individual samples have been arranged in descending ryegrass percentage. The considerable variation in composition checked quite well with the field observations made at time of sampling.

The comparison between the variabilities of the different sample sizes shows a general rise in efficiency up to the 64 cut size. However, in view of the relatively low numbers, as well as the errors associated with the dissection process itself, it would appear that *for this paddock*, 16 cuts gave as good a sample as the accuracy of the analysis allowed. For greater accuracy both the sample size and the number of cuts would have to be increased considerably. The comparison of the herbage from the enclosures shows the same change in composition in the paddock as seen in the smaller cuts. The mean of the two separate analyses gives results not far different from the multi-cut samples, whilst the analysis of the bulked herbage gives results again very close although some difference can be expected through taking the simple mean when actually each analysis should have been weighted for the yield in each respective enclosure. Variability between the duplicates in the frame samples is almost sure to be due to the size of sample dissected.

These results are considered by the writer as being very satisfactory for the estimation of the main constituents of the pasture. It is emphasized that to gain similar accuracy on a more mixed and variable pasture, much more work would be necessary, both in the field as well as in the dissection room, but this can be determined only after exploratory work in such a sward at actual sampling time.

Conclusion

Some may argue that all this effort at technique refinement is too involved and calls for too much work. The writer's attitude is, that unless the technique is correct, records and analyses on data and material from experimental setups are not of much greater value than those from unreplicated farm paddocks. After all, the amount of time and effort taken up in the laboratory is usually as great as that in the field, while a detailed measurement programme is usually the culmination of a long series of other unrelated observations and trials, the conclusions of which have lead up to the detailed type of experiment being considered in this paper. It is with this attitude and the background of experience and disappointment from some previous trial failures, that workers at Grasslands Division are continuing the search for techniques which will allow valid results to be secured.

It is again emphasized that this paper has been presented largely with the intention of bringing forward data relating to the many points of difficulty which can and do arise. It is realized that much of the material presented is perhaps not of *direct* application to work other than on relatively high production swards. However, it is felt that the principles discussed are of general application in all pasture work involving the grazing animal. For such work it is hoped that the data may be of value in drawing attention to the need for designing experimental setups that cater for the requirements of this complicated subject.

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CLASSIFICATION OF LAND IN THE WAIMEA COUNTY, NELSON, FOR FLUE-CURED TOBACCO

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Summary

Some 50,000 acres of alluvial land in the Waimea County, Nelson, have been surveyed and then classified in regard to potential value for flue-cured tobacco. Soil texture and good drainage are the most important factors in determining the suitability of land for such tobacco, under Nelson climatic conditions. Another factor of importance, particularly in the treatment of the land for tobacco, is the nature of the parent material from which the soils are derived. The classification for flue-cured tobacco soil adopted by the Cawthron Institute depends on

(1) an initial grouping of alluvial soils into six broad groups, based on marked differences in the nature of the parent material from which the soils are derived;

(2) the division of the soils within the broad grouping referred to above into six categories based on textural and drainage factors. Fine sands and sandy loams of good depth are the most suitable soils for flue-cured tobacco under Nelson climatic conditions.

Introduction

During the past 12 years, the acreage of tobacco in the Waimea County has increased from 2,000 to approximately 4,400 acres. This remarkable expansion of the flue-cured tobacco industry has been accompaneid by great improvement in quality of the cured leaf and per acre yield which has risen from 700 to nearly 1,200 lb. per acre.

Although several factors have contributed to the successful development of the industry, one of the most important has been the research work carried out by the Tobacco Research Station of the Department of Scientific and Industrial Research and the Cawthron Institute. This research has been concerned mainly with the culture of the tobacco crop, the control of disease and the curing of the leaf. At an early stage in the work, the importance of soil type in relation to quality of leaf was recognized and the Cawthron Institute was invited to carry out detailed soil surveys with a view to the classification of the land for flue-cured tobacco.

Owing to the mountainous and hilly nature of the Waimea County and the occurrence of large areas of very poor country unsuitable for cropping, it was deemed advisable to concentrate work on the alluvial soils, where experience had shown already the possibility of obtaining tobacco of satisfactory yield and quality. Some 50,000 acres of alluvial soil in areas climatically suited to tobacco culture have been examined by officers of the Institute; soil maps have been prepared and the land has been classified into different categories in relation to its value for flue-cured tobacco.

Influence of Geology on Soil Characteristics

The alluvial soils of the County are influenced greatly by the nature of the parent material to which the rivers and their tributaries have access. The geology of the County is very varied. Igneous rocks of different types, many sedimentary formations and a large deposit of Pleistocene gravels present distinctive features in different parts of the County.

Among the more important geological formations which contribute to alluvial soil formation may be mentioned, the ultra-basic rocks (Serpentines) of the Upper Moteuka river system, the granites of the Wangapeka and other tributaries of the Motueka river, the limestone, granites and basic igneous rocks of the Riwaka river system, the "Moutere Gravel" formation of the Motupiko, Tadmor, Wai-iti, Moutere, Dove and Stanley Brook rivers and the ultra-basic rocks, shales and slates of the Waimea river system. All these geological formations, frequently of very diverse chemical characteristics, exert a profound influence on the properties of alluvial soils in different parts of the County.

Another feature of interest in connection with the alluvial lands at Motueka and Appleby is the occurrence of certain soils, artificially prepared by the ancient Maoris who occupied these lands before the advent of the white settler. These soils which have been named "Maori" in the soil surveys of the Cawthron Institute have several distinctive features. They consist of sand or gravelly sand which has been spread to a depth of 10 to 14 in. over the natural alluvial loam. The soil was treated by the Maoris by burning scrub or other vegetable matter on the surface, thereby increasing very markedly its content of minerals.

Detailed Soil Surveys

As a preliminary to the classification of land for flue-cured tobacco culture, it has been necessary to carry out detailed soil surveys over the alluvial soils of the County. In these surveys the topsoil, subsoil and underlying horizons to a depth of 3 ft. have been examined. The principal sources of the parent rock contributing to the formation of the soils have been noted and samples of both topsoil and subsoil have been examined in the laboratory for texture, plant food and base status. Soil maps were then prepared based on the field and laboratory studies.

It was found that the alluvial soils of the County could be classified into broad groups dependent on the nature of the parent rock from which they were derived. In so far as potential use for flue-cured tobacco is concerned six of these broad groups are associated with distinctive characteristics. They are as follows:

(1) "Riwaka", derived from a great mixture of rock material including ultra-basic and basic rocks, granite, shales and "Moutere gravels".
"Riwaka" soils have very good inherent fertility and are fairly well supplied with all minerals, particularly phosphate. The nitrogen status of loams tends to be high.

(2) "Waimea", derived from ultra-basic rocks, shales, greywacke and "Moutere gravels".
"Waimea" soils have good inherent fertility and are well supplied with minerals, particularly magnesia. The nitrogen status of loams tends to be high.

(3) "Sherry", derived mainly from granite.
"Sherry" soils have a somewhat low inherent fertility; they are highly deficient in bases, particularly lime and magnesia. Deficiencies of boron and cobalt have also been identified on these soils.

(4) "Tapawera", derived mainly from ultra-basic rocks and "Moutere gravels".
"Tapawera" soils tend to be neutral or slightly alkaline in reaction; they have a relatively high content of available magnesia, sometimes attaining 9 mg. equivalents of replaceable magnesia per 100 g. of soil. They are somewhat low in phosphoric acid.

(5) "Motupiko", derived mainly from resortment of "Moutere gravels".
"Motupiko" soils have a rather low inherent fertility. They are acid being low in bases particularly lime. Deficiencies of magnesia, phosphate and boron have been identified on these soils.

(6) "Maori", artificially prepared soils by ancient Maoris.
"Maori" soils are well-supplied with bases and mineral plant food. Owing to the presence of a loam subsoil they provide excellent moisture conditions for intensive cropping.

With the exception of "Maori" soils, the six groups mentioned above include soils varying in texture from coarse sands to clay loams. These textural differences both of topsoil, subsoil and underlying strata to a depth of 3 ft. have been mapped by officers of the Institute and have been delineated on detailed soil maps on a scale of 4 in. to 1 mile.

Classification of Land for Flue-Cured Tobacco

Experience in the Nelson district, as in overseas countries, has shown that soil texture has a profound influence on both yield and quality of flue-cured tobacco. Optimum yield is not obtained unless moisture conditions are satisfactory. While poor drainage is inimical to both yield and quality of tobacco, droughty conditions caused by a gravelly subsoil are likewise unfavourable to yield. Quality of tobacco is highest on soils of somewhat low nitrogen status where the nutrition of the plant can be controlled by the use of artificial fertilizers in appropriate amount. As a general rule, fine sands or sandy loams of good depth are, under Nelson climatic conditions, the most suitable for securing both high yield and quality of tobacco.

It is clear therefore, that attention must be paid in any system of classification not only to texture of the topsoil but to the underlying horizons to a depth of at least 2 ft. 6 in.

While soil texture and moisture conditions of the soil in the Nelson district are the most important factors in determining the value of soils for tobacco, certain chemical characteristics exert considerable influence on both yield and quality. The incidence of "Black Root-Rot" of tobacco is most serious on soils which are neutral to alkaline in reaction and is lowest on well-drained acid soils. While over-liming the land favours the spread of "Black Root-Rot" on all soils, it may be anticipated that less trouble will be experienced on "Sherry" and "Motupiko" soils which are markedly acid in reaction.

Serious deficiencies of both boron and magnesia occur on several soils used for tobacco culture. While the extent of these deficiencies is influenced greatly by liming the land and also by the amount of rainfall during the growing period of the tobacco, the "Sherry" and "Motupiko" soils are particularly low in boron and magnesia, and

special care is necessary to guard against deficiencies of these elements affecting the tobacco crop. Lime should be used only in small applications on sandy soils, otherwise boron deficiency may be induced. The inclusion of ground dolomite or magnesite in the manurial programme is very desirable to secure high quality of leaf.

The "Tapawera" soils, on the other hand, frequently contain excessive amounts of available magnesia which might exert a harmful effect on the quality of the manufactured leaf. A high magnesia content of the leaf is associated with rapid combustibility a quality which is unsatisfactory to the smoker.

Any system of land classification for flue-cured tobacco in the Nelson district, must therefore take into account all the factors which affect both yield and quality of the crop. Texture, drainage and chemical characteristics are all important in relation to yield and quality of crop. Consideration must likewise be given to any factor which interferes unduly with the smooth conduct of cultural operations, e.g., irregularity of the surface or presence of stones.

In the classification now suggested for Nelson tobacco soils, texture and drainage are regarded as of major importance in determining the potential value of the land for the crop. The detailed soil maps of the Institute have, therefore, proved indispensable in the classification of the soils for flue-cured tobacco culture. The soils shown on the survey maps have been grouped into six categories according to their potential value for tobacco. The six categories are described below in order of suitability for flue-cured tobacco.

(1) Well-drained fine sands and sandy loams of good depth and not subject to river flooding. The depth of fine sand should be not less than 18 in. unless underlaid by sandy loam.

(2) Somewhat similar soils to those in category (1) but with textural conditions less perfect, e.g., underlying horizons rather too heavy or alternatively too open.

(3) Gravelly sandy loams and sands with rather open subsoils. This group of soils is satisfactory if irrigation can be practised but otherwise the tobacco crop is detrimentally affected by drought in dry seasons. Included in this category are certain soils liable to occasional flooding

(4) Soils of a somewhat heavy texture for high quality of tobacco. These are gravelly silt loams and light phase silt loams. Good yields are associated with tobacco culture on these soils but the leaf is frequently of comparatively poor quality, particularly in years of high rainfall. Soils of this textural class, belonging to the "Motupiko" group with lower inherent fertility, have given much better results in so far as quality of leaf is concerned than is the case with the same category belonging to the "Riwaka" group.

(5) Soils which are texturally too heavy for flue-cured tobacco. These are silt loams and light phase silt loams, underlaid by a heavier textured subsoil. They may possibly have some value for air-cured or fire-cured but not for flue-cured tobacco.

(6) Soils which are quite unsuitable for tobacco culture. These include clay loams, stony loams, peaty soils and soils with a high water table.

Some or all of the above categories are found in each of the parent soil groups previously described.

Typical mechanical analyses of soils included in categories 1, 4 and 5 of the textural classification are shown in Table I.

TABLE I. TYPICAL MECHANICAL ANALYSIS OF SOILS IN CATEGORIES 1, 4 AND 5

Lab. No.	Type.	Category.	Coarse Sand.	Fine Sand.	V.F. Sand.	Silt.	Clay.	Loss on Ignition.
			%	%	%	%	%	%
C181	Fine Sand	1	8·0	62·6	10·8	8·8	8·4	4·3
C721	Silt Loam (Light Phase)	4	10·9	27·5	9·6	26·9	18·2	7·0
3191	Silt Loam	5	6·1	20·6	14·4	33·0	17·7	4·7

The subsoils are :— C181, Sandy Loam ; C721, Sandy Loam and 3191, Silt Loam.
NOTE : Soils in Category 1 are very suitable for flue-cured tobacco culture.
Soils in Category 4 are rather heavy for high quality leaf.
Soils in Category 5 are too heavy for flue-cured tobacco.

In all, some 50,000 acres of alluvial soil in different parts of the Waimea County have been covered by detailed surveys and the soils classified by the methods outlined above for flue-cured tobacco culture.

Table II shows the classification of the soils by districts into the six textural categories.

TABLE II. TOBACCO SOIL SURVEY WAIMEA COUNTY
CLASSIFICATION OF ALLUVIAL SOILS FOR FLUE-CURED TOBACCO

Districts.	Soil Categories.						
	1	2	3	4	5	6	Total.
	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Motueka-Riwaka	1,324	1,279	573	1,314	525	3,088	8,103
Motueka Valley	633	606	372	381	824	770	3,586
Moutere Valley	Nil	814	340	2,377	1,015	2,397	6,943
Ngatimoti and Orinoco	13	65	60	305	329	453	1,225
Dovedale and Thorpe	15	174	488	617	682	1,033	3,009
Stanley Brook	6	100	484	100	321	1,435	2,446
Tapawera	364	289	542	290	959	2,273	4,717
Wakefield-Belgrove	Nil	396	626	1,129	1,167	792	4,110
Waimea Plains	Nil	1,397	2,013	2,016	3,339	7,491	16,256
Total	2,355	5,120	5,498	8,529	9,161	19,732	50,395

NOTE : Categories 1 and 2 : good to very good.
,, 3 and 4 : satisfactory under certain conditions.
,, 5 and 6 : unsuitable for flue-cured tobacco.

The data presented in Table II show that out of a total of 50,395 acres included within the surveys, only 7,475 acres fall within categories 1 and 2 which are regarded as good to very good for flue-cured tobacco. Some 14,000 acres fall within categories 3 and 4, which under favourable conditions may be used for flue-cured tobacco but which are not entirely satisfactory. Nearly 29,000 acres which fall into categories 5 and 6 are unsuitable for flue-cured tobacco.

A feature of interest in the data for different districts is the relatively large area of suitable land in the Motueka-Riwaka and Motueka Valley districts. These two districts account for more than half of all the land in the Waimea tobacco growing areas, falling within categories 1 and 2.

Distribution of Tobacco in the Waimea County

Table III shows the distribution of tobacco, practically all flue-cured, in the Nelson County during the 1948-49 season.

Table III. Distribution of Tobacco 1948-49

District.	*Acres*
Motueka-Riwaka	2,184
Motueka Valley	737
Moutere Valley	188
Ngatimoti and Orinoco ...	272
Dovedale and Thorpe ...	225
Stanley Brook-Tapawera ...	299
Wai-iti	424
Waimea...	65
Total	4,394

The data presented in Table III show that approximately half of the total acreage of tobacco is concentrated in the Motueka-Riwaka district. The Motueka Valley, from Whakarewa to Ngatimoti, is the next most important tobacco growing district. The remaining 1,500 acres are distributed in a number of sheltered valleys in different parts of the county. Of these the Dovedale-Thorpe and the Ngatimoti-Orinoco districts are best known for the quality of the tobacco and the great interest shown by farmers in tobacco culture.

Correlation of Flue-Cured Tobacco with Tobacco Soil Maps

Although data for the 1948-49 season are not available, showing the exact distribution of tobacco on the different soils of the Waimea County, land-use surveys made in the Motueka-Riwaka district in 1940-41 gave a good correlation between land categories 1 and 2 and the actual distribution of tobacco. Some 78 per cent of the tobacco grown in the Motueka-Riwaka district in that season was located on land classified as coming within categories 1 and 2, while no less than 85 per cent of the total acreage of tobacco was located on categories 1, 2 and 3. The crop survey confirmed, therefore, the value of the classification of land for flue-cured tobacco in the Motueka-Riwaka district.

Future Development of the Tobacco Industry in the Waimea County

The flue-cured tobacco industry has proved a profitable one to Nelson farmers and there has been a steady expansion of 200 to 250 acres annually over the last ten years. The total yield of tobacco for the district is approximately five million pounds per annum. The total consumption of tobacco manufactured in New Zealand is of the order of eight million pounds yearly. This suggests that approximately 60 per cent of the tobacco manufactured in New Zealand is grown in the Nelson District. There would not appear to be any reason why the percentage of New Zealand leaf in manufactured tobacco should not be increased to at least 75 per cent, leaving 25 per cent available for high grade American leaf. The execution of such a policy would require an increase of some 600 acres over the 4,400 acres grown in the 1948-49 season. The data presented in Table II indicate that little

difficulty should occur in meeting this demand. If, however, export of New Zealand leaf to countries such as Australia or Great Britain is contemplated, more careful scrunity of the available acreage of land is required. The total acreage coming within categories 1 to 4 is approximately 20,100 acres, but of this total some 5,400 acres are located on the Waimea Plains which are used extensively for green peas, tomatoes and vegetables. As the Waimea Plains are more exposed to winds, it would be preferable if they were excluded from the available tobacco land and reserved for green peas, vegetables and seed production.

In other parts of the district, orchards, hops and small fruits compete with tobacco for use of land in categories 1 to 4. The total acreage of these crops within the tobacco growing districts is probably 1,800 acres. Excluding these areas and those of the Waimea Plains, the total area of possible tobacco land is reduced from 20,000 to 12,900 acres.

After making due allowance for the maintenance of other intensive crops grown in the County and the desirability of spelling a proportion of the tobacco land each year, it is doubtful whether an annual acreage of flue-cured tobacco greater than 6,000 acres, can be recommended with safety and satisfaction to the industry.

The data suggest that further development of the flue-cured tobacco industry must be associated with greater use of land in categories 3 and 4. The Moutere Valley and the Motueka-Riwaka districts appear to possess the best prospects for a relatively large increase in the acreage of tobacco.

In order to obtain the best results from land in category 4, great care in management is required. Owing to the somewhat heavy texture of the soil, the nitrogen status tends to be too high for leaf of high quality. Nitrogenous manures should be used sparingly and the amount of phosphate and potash increased on soils of this category. Further experimental work is required in the treatment and cropping of this land before the best results with flue-cured tobacco can be expected.

EXPERIMENTS ON THE PACKING AND STORAGE OF BUTTER

X. EXPERIMENTS ON PREDICTING THE STORAGE LIFE OF BUTTER

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(*Received for publication, 22 August 1949*)

Summary

Assessment of the keeping properties of butter has been attempted by means of laboratory and accelerated storage tests.

The principal factors influencing the storage life of butters made from finest quality cream under commercial storage conditions (14°F.) are considered to be: (a) acidity of cream at churning (or pH of butter); (b) salt content; and (c) degree of contamination by copper and iron. These factors had well-defined effects on experimental factory butters manufactured under conditions which ensured that only one factor was varied in each trial. It was not possible, however, to predict the storage life of individual samples of butter on the basis of their acidity, salt or copper and iron contents.

Accelerated tests of one to three months' duration at temperatures of 35°, 45° and 60°F. were also insufficiently accurate for use in evaluating storage life of factory butters at 14°F.

In commercial butters, chemical changes causing flavour deterioration would be even more complex than was the case with these experimental factory butters. Moreover, the range in variation of grade scores for commercial New Zealand butters after storage is normally so small that it would not be possible to differentiate between samples by means of laboratory or accelerated storage tests.

A rapid "oven" sorting-out test which gave promise as a method for detecting incipient oxidation, or the presence of traces of copper responsible for this defect, is described.

Introduction

The quality of well-manufactured butter is, for the most part, dependent on its flavour, and the process of butter manufacture is so designed that the butter will maintain its freshness even during a lengthy period of storage. The grade score allotted to butter before marketing is virtually a prediction of its keeping quality, for experienced judges of butter quality can readily detect incipient changes in flavour which are likely to become accentuated during storage and so further detract from its freshness.

Other means of assessing keeping quality of butter depending on laboratory tests have been proposed. They are not alternatives to grading methods based on flavour perception but are designed to supplement them by providing rapid means of tracing causes of defects with a view to their immediate eradication.

Butter flavour results from a complex combination of factors, viz:—

(a) *Substances initially present*:
- (1) Natural flavouring substances.
- (2) Diacetyl ("butter-aroma") resulting from fermentation (souring) of lactose by starter organisms.
- (3) Taints—usually derived from feeds.
- (4) Acids—mainly lactic.
- (5) Salt.

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(*b*) *Substances developing during storage*:

(1) Biochemical origin, i.e. taints derived from metabolic products of bacterial and mould action (e.g. hydrolysis of fats (rancidity); hydrolysis of proteins (putrefaction).

(2) Chemical origin (i) hydrolysis of fats (rancidity), (ii) oxidation of fats and related substances.

Changes in flavour during storage may therefore be brought about either by (a) loss of original flavouring substances, or (b) development of taints.

Laboratory Methods for Predicting Storage Life of Butter

Methods include tests for specific organisms, and for metallic contaminants as well as accelerated storage tests at elevated temperatures.

A positive reaction in the catalase test, as used for Danish and Dutch butter (1) has been interpreted as denoting poor keeping properties, since starter organisms contain no catalase and its presence indicates the growth of undesirable organisms. Loftus-Hills, Scharp, and Bellair (2), however, working with Victorian salted butter (a product similar to that of this country) found no correlation between keeping quality and catalase test.

Nelson (3) considered that the keeping quality of both salted and unsalted butter could be evaluated with a high degree of accuracy from the number of certain rod-shaped bacilli in the curd. Thomas (4) and Minster (5) used simple bottle-incubation tests for unsalted butters in which the rate of development of "off flavour," as measured by odour, was found to agree fairly well with findings in practice. Minster places less reliance on this test than on more complex ones devised for measuring catalase, reductase, acidity and gas formation by organisms present. Arup and van Gilmour (6) on the other hand, found no agreement between biochemical and chemical tests before storage and the keeping quality of butter.

Australian workers (7), (8), (9) emphasized the necessity for controlling the pH and the copper and iron contents of salted butters designed for long storage.

Grant and White (10) carried out experiments on keeping properties of butters over a wide range of temperatures (30° - 90°F.) and concluded that the correlation between flavour tests was better with chemical (acidity) tests than with bacteriological tests, but that the assessment by tasting remained the best method of judging keeping quality.

Jacobsen *et al.* (11) also compared accelerated holding tests at 30° and 70°F. with the keeping properties of butters in cold storage and obtained fairly good correlations. They pointed out, however, that the assessments made from accelerated tests at 30°F. were related more to chemical changes, those at 70°F. to bacteriological defects.

Grant *et al.* (12) recommended a serum-fluorescence method (using ultra-violet light) for differentiating, under accelerated storage conditions, variations in keeping quality. They concluded that oxidation of the fat fraction contributed little to flavour deterioration in salted butters. This observation is contrary to the views of Barnicoat and Palmer (13) and Barnicoat (14) who showed that flavour defects, even of the common "stale storage" type, could be promoted in butter by means of traces of pro-oxidant metals (copper and iron) long before the appearance of changes detectable by the most sensitive chemical

methods. These authors believed that loss in freshness of flavour in well-made butter during storage is, to a great extent, promoted by oxidation.

Attempts to evaluate keeping properties of butter by comparing stabilities of the separated fats towards oxidation, though suitable for use with edible oils, including ghee (dry butterfat) (15), have not given encouraging results with butter (16) (17), probably because of its emulsive nature.

While the present New Zealand method of grading has proved satisfactory for assessing keeping quality of butter, rapid methods (laboratory or accelerated tests) for detecting differences in keeping properties of commercial butters, in order to trace faults in manufacture, would be a useful adjunct to the existing system. Many of the overseas findings are, however, inapplicable under our conditions where the only butter produced is of the mildly salted, sweet-cream variety, made from efficiently pasteurized creams usually of good quality.

The principal factors influencing the storage life of New Zealand butters are considered to be:—

(a) quality of cream received;
(b) acidity of cream at churning (or pH of butter when made);
(c) salt content;
(d) degree of contamination by copper and iron; and
(e) temperature level and duration of storage.

The effect of temperature level and duration of storage on the quality of New Zealand butter (e) has already been reported (18).

In this paper the possibility of using laboratory or accelerated storage tests for predicting the storage life of commercial butters is discussed. The relative importance of (b), (c) and (d)* has been studied with experimental butters in which only one of these factors at a time was altered. In order to ensure that observed differences were really due to the conditions imposed by the experiment, control churnings (sweet cream butters of pH 6.6-6.8 containing 1.5 per cent salt) from the same creams were made daily. Control butters were graded initially at 93 points or more and were characteristic of well-made New Zealand butters.

The results are discussed in four separate but inter-related sections: Section (1) records the averaged effects on losses in grade score of butters during storage promoted by different degrees of (a) acidity, (b) salting, and (c) contamination by iron and copper; in section (2) attempts to predict keeping properties of individual butters using as a basis values calculated in section (1) are described; in section (3) the possibility of using accelerated-storage tests (at 35°F. or higher) for evaluating the storage life of butters at 14°F. is discussed; and in section (4) there is a description of a simple, rapid fat-oxidation test which showed promise for "sorting-out" butters containing traces of oxidized fat or copper from normal samples.

Experimental

Butters used for these experiments were manufactured at the Dairy Research Institute's factory from finest quality cream pasteurized by

* As the butters were made from "finest" quality cream one important variable (a) has thereby been eliminated.

means of a vacreator. They were examined by Government graders before and after storage.

Peroxide values of fats were estimated by Lea's method (19), fat aldehyde values by Schibsted's method (20), and accelerated fat-oxidation tests were carried out by means of an "oven" test described in section (4).

RESULTS

(1) *Effects of Acidity, Salt and Traces of Iron and Copper on Storage Life of Butters*

The average effects of variations in acidity, and in salt and metal contents on loss in grade score of butters held in commercial storage for six to twelve months at 14°F. were as follows:—

(a) *Acidity*

(Results from 37 butters churned from pasteurized, finest cream, 40 per cent fat, 1.5 per cent salt, churning acidity of cream 0.065-0.49, butter pH 4.4-6.8.) With butters made from cream of acidity 0.08 or higher, loss in grade score increased on the average by 0.035 point/month at 14°F. for each 0.01 per cent rise in churning acidity.

(b) *Salt content*

(Results from 20 sweet cream butters of pH 6.6-6.8, made from pasteurized finest cream):

AVERAGE SALT CONTENT OF BUTTER (%)	AVERAGE INCREASE IN GRADE-SCORE LOSS PER MONTH
None (unsalted)	Nil-control
1.5	0.02
2.5	0.02
3.5	0.08
4.5	0.04

There was a trend for the more highly salted samples to have poorer keeping properties, probably because of the effect of salt in increasing fat oxidation in butters during storage (Table I in reference (21)).

(c) *Iron and Copper Content*

(Results from 27 butters made from pasteurized finest cream; 1.5 per cent salt):

TYPE OF BUTTER	ADDED METAL CONTENT	AVERAGE INCREASE IN GRADE SCORE LOSS PER MONTH
Sweet cream (pH 6.6-6.8)	0.1 p.p.m. copper	0.02
	0.3-0.5 „ „	0.05
	0.5 „ iron	0.15
	0.5 „ iron + 0.5 p.p.m. copper	0.20
Ripened cream (pH 6.2-6.4)	0.5 p.p.m. copper	0.25
	0.5 „ iron	0.02

The effects of similar additions of iron or copper to sweet and ripened cream butters differed markedly, the reasons for which have been discussed in an earlier paper of this series (14).

It will be seen that increases in acidity, and in salt and copper and iron contents had deleterious effects on the storage life of butter. While these effects are, in general, well recognized by buttermakers, results from this investigation (obtained from adequately controlled trials in which one factor only at a time was altered) gave values

which indicated the relative importance of the individual factors concerned. It is apparent that metallic contamination is the most important factor concerned with deterioration under present New Zealand manufacturing conditions.

(2) *Attempts to Predict the Storage Life of Individual Butters*

Attempts to use the well-defined trends in alterations in keeping properties resulting from differences in acidity, degree of salting, and contamination by iron and copper as a basis for predicting storage life of individual butter samples proved unsatisfactory, even under the simplified experimental conditions employed for these trials.

(a) *By acidity (or* pH *values)*

Correlation between churning acidity and loss in grade score of butters (held for six months at 14°F.) was highly significant ($r = 0.974$) but there was a high standard error of estimate in storage losses predicted from the regression equation, differences being at least ± 35 per cent, e.g., samples with predicted losses of 3 actually lost from 2 to 4 points.

(b) *By salt content*

Variations between predicted and actual losses were about ± 45 per cent.

(c) *By iron and copper contents*

Variations were of the same order as for (b).

(3) *Accelerated Storage Tests*

Accelerated storage tests depend on the constancies of the ratios between the rates of deterioration, i.e. loss in grade score, at the testing and storage temperatures. Factors expressing the ratio between losses in grade score at 35°, 45°, or 60°F. and 14°F. were obtained for butters with different salt, iron and copper contents and for other experimental butters (18).

The following ratios, obtained from 19 butters of different salt contents, were typical of other results:—

Type of Butter	Factors ratios of grade-score losses at 14°F. to losses at		
	35°F.	45°F.	60°F.
Unsalted	0.16	0.10	0.07
1.5 per cent salt	0.16	0.11	0.08
2.5 „ „	0.17	0.13	0.09
3.5 „ „	0.25	0.16	0.12

The factors are consistent among themselves, but when applied to the rates of grade score loss observed for individual butters held for one, two or three months at 35°, 45° or 60°F., the predicted losses for butters held 6-12 months at 14°F. agreed poorly (± 50 per cent) with the losses actually found.

Accelerated storage tests, even with butters made under simplified experimental conditions whereby only one factor concerned with deterioration was altered at a time, failed to differentiate satisfactorily between samples of various types. Predicting the storage life of commercial butters by laboratory or accelerated storage tests would therefore be impracticable, for a variety of factors are responsible for their deterioration, and well-made butters of the New Zealand type normally exhibit a very small range of differences in keeping quality.

(4) *Accelerated Fat-Oxidation Tests for Detecting Traces of Copper*

Butter containing traces of iron and copper rarely gave chemical evidence of fat oxidation, even when their flavours were impaired. As estimations of iron and copper in butter are tedious and expensive to undertake as routine tests, experiments were made with a simple accelerated fat-oxidation ("oven") test.*

Results from over 20 butters (before or after storage) containing added iron and copper were as follows:—

METAL CONTENT OF BUTTER	FAT ALDEHYDE VALUE/ML. FAT	
	INITIAL	AFTER HEATING FOR 4 HOURS AT 110°C. ("OVEN" TEST)
Controls (containing approx. 0.1 p.p.m. Cu and 0.5 p.p.m. Fe)	0.1 or lower	2-4
plus 0.1 p.p.m. Cu	"	5-7
" 0.2 " Cu	"	6-7
" 0.5 " Cu	"	7-8
" 2.5 " Fe	"	2-4
" 5 " Fe	"	3-5
Butterfat + 0.1 per cent oxidized (bleached) butterfat.	"	6

Under the specified conditions for carrying out this simple "oven" test, the presence of traces of oxidized fat or of copper in excess of normal amounts was evident from the increased fat aldehyde values of the heated fats. The test, however, was not sensitive to traces of iron, which, as already explained (13) (14), can promote very objectionable taints in butter, apparently through oxidation of lecithoproteins without much action on the unsaturated triglycerides.

Accelerated fat oxidation tests might prove of value in practice for differentiating stabilities of individual butter samples, particularly when incipient oxidation has been induced by copper contamination. After establishing the response to this test of normal, well-made butters (manufactured from creams of similar quality, and of similar pH values and salt contents), assessment of stabilities towards oxidation would be a relatively simple "sorting-out" procedure.

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* For this test butters were weighed into flat-bottomed glass dishes, the ratio surface area : depth of fat being constant. The dishes were kept in an electric oven at 110°C. for four hours, after which 1 ml. samples of fat were removed for analysis (19) (20).

In order to avoid destroying the butter emulsion, acceleration of fat oxidation by means of light and ultra-violet light was also attempted, but the catalytic effect of both exceeded that of the metals and obscured the results.

Temperatures lower than 110°C. gave similar results to those found at 110°C. but lengthened the period of testing unduly. Fat aldehyde values were preferred to fat peroxide values as a measure of oxidation, mainly because peroxide values in butter are usually of a low order which renders differentiation between samples difficult.

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THE EFFECT OF HOT-WATER TREATMENT ON THE GERMINATION OF DREADNOUGHT WHEAT

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(*Received for publication, 17 March 1950*)

Summary

Dreadnought wheat may be partially dormant in some seasons, when it requires a period of after-harvest ripening before it will germinate fully.

This dormancy can be broken by moistening the seed and chilling it at 41° F. for 155 hours.

Hot-water treatment of the seed during the dormant period increases dormancy and further retards germination.

Chilling of treated, dormant seed enables it to germinate rapidly and completely.

Hot-water treatment of fully-mature seed has no effect on germination.

Introduction

Dreadnought wheat is reputed to be more susceptible than other varieties to germination injury resulting from hot-water treatment (H.W.T.) for the control of seed-borne disease.

There is no doubt that slow and erratic strikes have followed the use of hot-water-treated Dreadnought seed, but there is no direct evidence that this has been due to the effect of the treatment, because no germination tests have been made on the seed before and after treatment. The results of the trials described below show that hot-water treatment of dormant seed may considerably retard its germination.

Material and Methods

Dreadnought seed harvested at the Agronomy Division in 1941 and 1942, and seed from six different farm crops harvested in 1943, was used in the tests. Since there were no marked differences between the six 1943 lines, only the results from the poorest germinating line are given, in order to simplify presentation.

The hot-water treatment was worked out by the Plant Diseases Division, Department of Scientific and Industrial Research, and is used in routine treatments of seed wheat at the Agronomy Division. The seed is soaked for five hours in water at 70° F., steeped for ten minutes in water at 127° F., cooled for not less than three minutes in water at about 60° F., and then dried.

Germination tests were carried out on wet blotting paper in Petri dishes in a cabinet held at 70° F. ± 2° F.

The chilling was done in a refrigerator in ordinary domestic use, in which the temperature fluctuated from 31° to 37° F. in the inner, and from 38° to 46° F. in the outer compartment. Since the machine was not opened during the night, it seems likely that the mean temperature would be nearer the minimum than the maximum recorded, and it is suggested that the mean temperature in the inner compartment would be about 33° F., and in the outer about 41° F. Preliminary tests showed that chilling the dry seed at either temperature had no effect on germination, and that chilling moist seed at the lower temperature severely reduced germination, probably through freezing. In the data presented, "chilled" seed means seed moistened, either by full hot-water treatment or by soaking for five hours at 70° F., then held at about 41° F. for the times specified.

Results

In May 1942, germination tests were carried out on seed harvested in January 1941 and January 1942. At this date the 1941 line was fully matured, and hot-water treatment only slightly retarded germination. The 1942 line, however, was not yet mature, and hot-water treatment had a somewhat greater effect on germination. The percentage germination figures are given in Table I below.

Table I. Germination of Dreadnought Wheat on 26 5 42

		Percentage of Seeds germinated after		
		3 days.	6 days.	10 days.
1941 seed	Untreated	92	94	94
	Hot-water-treated (mean of 3 samples)	36	91	93
1942 seed	Untreated	12	56	78
	Hot-water-treated (mean of 3 samples)	19	45	71

Further tests carried out in August 1942 and March 1943, show clearly the progressive lessening of dormancy, and also the fact that hot-water treatment of dormant seed increases its dormancy but does not injure its viability.

In August 1942, a sample of the 1942 seed was hot-water treated while still somewhat dormant; the treatment considerably retarded germination, but this same seed was, by March 1943, capable of 94 per cent germination in six days.

The moisture content of the seed was determined, because it had been suggested that this might affect the germination; the figures, however, show that this factor is not responsible for the variations.

Table II. Germination of 1942 Seed on Various Dates

		Moisture content. (%)	Percentage of Seeds Germinated after		
			3 days.	6 days.	10 days.
Untreated	26/5/42		12	56	78
	17/8/42	14·4	60	80	92
	16/3/43	14·2	100	—	—
Hot-water-treated	26/5/42		19	45	71
	17/8/42	13·2	40	60	78
	16/3/43	14·2	76	94	94

Table III. Germination of 1942 Seed on 21/6/43

	Percentage of Seeds Germinated after			
	2 days.	3 days.	6 days.	10 days.
Untreated	98	98	98	98
Hot-water-treated, August 1942	66	90	98	98
Hot-water-treated, June 1943	96	100	100	100

A final test was made in June 1943 on the same line, using (a) untreated seed, (b) seed hot-water treated in August 1942, and (c) seed hot-water treated in June 1943. This offers convincing evidence that hot-water treatment does not affect the germination of fully mature Dreadnought seed.

Trials with 1943 seed.

Germination tests with six lines of 1943 Dreadnought seed showed that all were dormant to some extent, though less so than the previous season's crop. Germination figures for the lowest germinating lines are given in Table IV below.

TABLE IV. GERMINATION OF 1943 SEED ON VARIOUS DATES

	Percentage of Seeds Germinated after					
	3 days.	6 days.	7 days.	10 days.	14 days.	24 days.
23/3/43	20	28	—	64	86	—
12/4/43	22	—	40	62	88	96
15/6/43	62	—	88	100	—	—

Consideration of these results suggested that, since heating wet seed increased its dormancy, chilling the wet seed might reduce the dormancy. Hyde[1] has shown that newly-harvested Algerian oats may germinate slowly and erratically at about 70° F., but if the moist seed is chilled for 60 hours at 40 - 50° F. it will germinate rapidly and completely at 70° F. He also showed that dormancy was intensified by holding the moist seed at 70° F. or over for six days or more. The effect of chilling untreated and hot-water-treated Dreadnought wheat is shown in Table V.

TABLE V. EFFECT OF HOT-WATER-TREATMENT AND CHILLING ON PERCENTAGE GERMINATION OF 1943 SEED, 12/4/43

No. of days:	1	2	3	4	7	10	15	24
Untreated	0	14	22	34	40	62	88	96
Hot-water-treated	0	6	16	22	36	58	70	86
Hot-water-treated then chilled 85 hr.	14	36	38	48	66	74	92	98
Chilled 155 hr.	94	94	94	94	94	94	94	94

A further test was carried out two months later; in this test the hot-water-treated seed, surprisingly, germinated slightly more rapidly than the control. It is just conceivable that the temperature (45°F.) of the water in which the treated seed was cooled was low enough to counteract the effect of the heat-treatment, but this explanation is not very convincing. However this may be, it is clear that chilling the treated seed for 155 hours at 41°F. was sufficient to counteract the heat treatment and also to break the dormancy completely.

TABLE VI. PERCENTAGE GERMINATION OF 1943 SEED ON 15/6/43

No. of days:	1	2	3	7	10	14	16
Untreated	0	48	62	88	100	100	100
Hot-water-treated	0	56	72	86	92	96	100
Hot-water-treated then chilled 155 hr.	78	96	96	98	98	98	98

Discussion

"Dormant" seed is viable seed that for some reason is unable to germinate under conditions suitable for germination.

Failure of viable seed to germinate may be due to any one or more of the following causes:—

(a) A hard seed-coat that prevents the uptake of moisture. This is common in the leguminosae, and is easily remedied by cracking or chipping the seed-coat.

(b) Impermeability to oxygen of the inner seed-coat. Bishop[2] considers that this is the most probable cause of dormancy in malting barley, and has shown that removal of a small portion of the testa over the embryo permits immediate germination of such dormant seeds.

(c) Physiological dormancy. In this case the seed appears to have a definite cold requirement that must be satisfied before the seed can germinate.

Dreadnought wheat may have a dormant period of variable duration and intensity after harvest; and since hot-water treatment increases this dormancy, and chilling the seed reduces it, it is apparent that the dormancy of Dreadnought falls into class (c). Dormant seed of this type can acquire the requisite amount of cold in ordinary farm-storage during the winter, and it is noteworthy that little improvement in germination takes place during the three or four months after harvest while temperatures are still fairly high.

Moistening the seed and chilling it overcomes dormancy in a few days, though chilling dry seed (with a normal moisture-content of about 14 per cent) for a few days is not effective; this is easily understood, since it is well known that the effect of temperature on seeds is directly correlated with their moisture-content.

It is interesting to speculate on the relationship between this type of dormancy, which is broken by chilling, and the winter-habit of certain cereals which is altered by vernalization. At first sight it seems reasonable enough to suppose that the cold-requirement of the seed for germination is linked with the cold-requirement of the plant for earing, but there are considerable difficulties in accepting this suggestion.

Bell[3], in vernalization trials with wheat, barley, and oats, found that many of the varieties that showed the greatest acceleration in germination showed no acceleration in earing, and, conversely, winter varieties in which vernalization produced the maximum difference in earing-date showed little or no acceleration of germination.

Similarly, Hyde[1] has shown that Algerian oats may be strongly dormant, yet this variety is frequently sown in spring for a seed crop, and cannot be considered a winter variety.

The period of six days of chilling required to break dormancy is very much less than the 42 days or so required for full vernalization[4], but, in view of the above considerations, it is unlikely that the difference is purely quantitative. It is more probable that the effects of chilling on germination and on acceleration of earing are quite distinct; in germination it is likely to be due to increased enzyme activity,[5] while in vernalization, which is only effective in the developing seed, it may be due to production of the still hypothetical "florigen."

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RED-CORE (*Phytophthora fragariae*) OF STRAWBERRIES

By H. C. SMITH, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

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Summary

(1) Strawberry root-rot which has been serious in New Zealand for many years is shown to be caused by red-core (*Phytophthora fragariae* Hickman).

(2) Red-core is recognized by stunting, wilting or death of the plants, decay of the root-system, and a reddish-brown discoloration in the stele of infected roots.

(3) Morphology of the fungus and symptoms of the disease correspond with those given for red-core in other countries.

(4) Inoculations have proved the pathogenicity of the fungus.

(5) Red-core appears to be a major factor in causing strawberries to be grown as an annual crop in the Auckland District.

(6) The disease is widely distributed in the Dominion.

(7) Severity of infection is greatest in soils with a high moisture content.

(8) Control may be secured by planting disease free runners in clean ground.

INTRODUCTION

Root-rot of strawberries has caused serious losses in most provinces in New Zealand for many years (Woodhead and Chamberlain, 1940). Bailey (1947) stated that the disease was primarily associated with wet soil conditions. Although the symptoms corresponded with those recorded for red-core in Scotland (Alcock, 1929) and England (Hickman, 1940) examinations and isolations from diseased roots made over a period of years showed no evidence of *Phytophthora,* only non-pathogenic fungi e.g. *Cylindrocarpon, Fusarium* and *Pestolozzia* spp. being isolated. In the winter of 1948, however, oospores of *Phytophthora fragariae* were observed in the stele of infected strawberry roots and the fungus was isolated.

SYMPTOMS

During the winter, spring and early summer, infected strawberry plants are found in all stages of root decay with corresponding foliage symptoms. With slight infection plants show only a slight stunting and reddening of older leaves, but with severe infection, when the whole root system is destroyed, plants show pronounced stunting and leaf reddening, and finally, with the advent of drier conditions, wilting and death. Leaves of infected plants lose their lustre and become reddened along the petioles and around the leaf margins. Later formed leaves are stunted with small rolled leaflets and short petioles (Fig. 1). Diseased roots first become water-soaked and grey in appearance and finally change to dark-brown. The most typical symptom of the disease is a reddish-brown discolouration of the stele of apparently healthy new roots. This condition may extend for a considerable distance within recently invaded white roots (Fig. 2). With warmer and drier conditions the infected roots decay and identification of the disease becomes difficult.

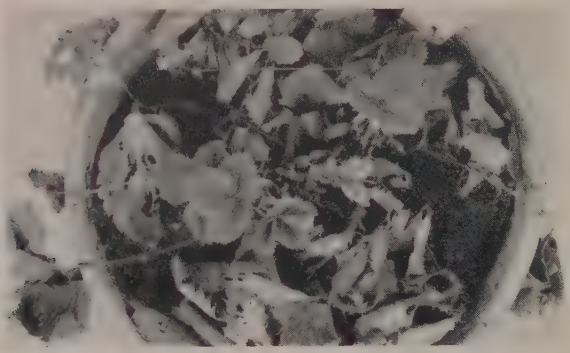

FIG. 1.—Stunted red-core infected strawberry plant. (X ½.)

Photo: R. I. Hughes.

FIG. 2.—Red-core infected strawberry plant with some roots split to show discolouration of stele. (X 1¼.)

MORPHOLOGY

Vegetative hyphae and oogonia were observed in the phloem of the vascular cylinder of the root and in the root tip. Sex organs were formed within the root tissue two to three weeks after infection (Fig. 3). Antheridia are amphigenous, 12-20 x 8-16μ (av. 16 x 12μ). Oogonia are pyriform with smooth, brown walls, 26-36μ diameter (av. 30μ), while oospores are spherical, smooth, thin walled, 25-35μ diameter

(av. 28μ) (Fig. 4). In culture on oatmeal agar the oogonia and oospores are slightly larger 28-40μ diameter (av. 32μ) and 26-38μ diameter (av. 30μ) respectively.

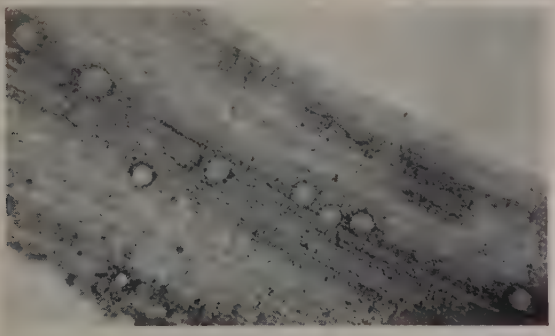

FIG. 3.—Strawberry root infected with red-core and showing sex organs of *Phytophthora fragariae* along the *stele*. (X 100.)

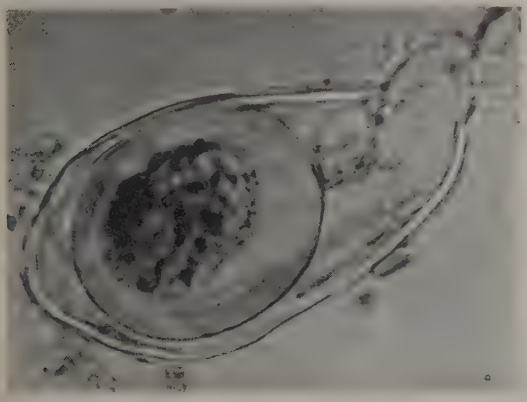

FIG. 4.—Oogonium and oospore of *Phytophthora fragariae* teased from a red-core infected root. (X 1000.)

Sporangia develop readily from cut ends of infected roots placed in water at 15-20°C. (Fig. 5). They are obpyriform 24-80 x 12-48μ (av. 49 x 31μ). Zoospores are liberated by rupture of the thinner apical portion of the sporangial wall. Sporangial proliferation was observed on roots left in water for several days. As many as six Sporangia were observed within the original empty sporangial wall.

ISOLATION

The method described by Hickman (1940) was followed. Infected strawberry roots with apparently healthy white cortex, and red discoloured stele were first washed in water and then disinfected in either 50 per cent ethyl alcohol or 0.35 per cent calcium hypochlorite for three minutes. They were then washed in three changes of sterile water. Pieces of smaller roots and steles of larger ones were placed

singly on a drop of water agar. Over each piece of tissue was poured melted water agar. After being held at 20°c. for about five days the plates were examined under the microscope. Those cultures showing no growth or only a few unbranched, non-septate, non-sporing hyphae were retained and transferred to oatmeal agar. Growth on both potato dextrose agar and oatmeal agar was slow, on the latter media being 3 in. in 20 days. Growth failed to take place on malt extract agar. Isolations were successful from July till October but in January to April when the fungus was not active only non-pathogenic fungi were obtained.

Fig. 5.—Sporangia growing from a strawberry root infected with red-core. (X 140).

Inoculations

Healthy strawberry plants of four varieties were inoculated with oatmeal agar cultures of *Phytophthora fragariae*. The plants were washed, and a piece of culture placed in direct contact with the roots. They were then repotted and well watered. Numbers of infected plants were recorded after four weeks, results being given in Table I.

Table I. Red-core Infection in Strawberry Plants Inoculated with *Phytophthora fragariae*

Variety.	Number Inoculated.	Number With Red-core. (After 4 Weeks)	Per Cent. Infection.
Madame Melba	3	3	100
Captain Cook	15	14	93
Ettesburgh	12	3	25
Chapman's Seedling	5	0	0

From results given in Table I it may be seen that all inoculated Madame Melba plants developed the disease and only one out of 15

Captain Cook plants failed to become infected, thus indicating that these two varieties are highly susceptible (Fig. 6). On the other hand Chapman's seedling and Ettesburgh varieties appear to show resistance. Twelve Captain Cook and three Ettesburgh plants which were not inoculated but were held under the same conditions remained healthy.

FIG. 6.—Effect of red-core on strawberry plant.
Left: Inoculated with *Phytophthora fragariae*.
Right: Uninoculated.

INCIDENCE

Examination of material from Auckland, Wellington and Canterbury has shown that red-core occurs in these three provinces. In the Auckland Province inspection of nurseries showed the disease was widespread, infection occuring in eight of fifteen nurseries visited. In two nurseries it was found that the amount of red-core infection in a runner bed varied from zero in the well drained parts to 100 per cent in the low lying areas. A noticeable feature of the nursery survey was the low incidence of red-core in those nurseries with both a relatively low rainfall and light textured soil (see Table II).

TABLE II. THE EFFECT OF SOIL TYPE AND RAINFALL ON THE SEVERITY OF RED-CORE IN STRAWBERRY NURSERIES

Soil Type.	Annual Rainfall. (in.)	Red-core Severe.	Infected Nurseries Slight.	Clean Nurseries.	Total.
Light	30 - 60	0	2	7	9
Light	Over 60	2	0	0	2
Heavy	30 - 60	4	0	0	4

In the fruiting beds at Auckland, at least one of the three following conditions was associated with severe red-core infection: (a) growing of infected plants for a second year crop, (b) setting out runners on ground infected by a previous crop, (c) setting out runners obtained from nurseries known to contain infected plants. The degree of red-core infection in plants from the same nursery varied considerably in different fruiting beds. These variations were found to depend on soil conditions in the fruiting beds, and ranged from zero with early deep cultivation to 50 per cent where cultivation was shallow and planting late. In general the trend was for increased severity of the disease under those conditions which increased the moisture content of the soil. Five lines of plants from apparently clean nurseries and five lines from infected nurseries were examined in the fruiting beds (on new ground) for red-core infection. The results are shown in Table III.

TABLE III. THE SPREAD OF RED-CORE TO NEW FRUITING BEDS ON PLANTS FROM DIFFERENT NURSERIES

Clean Nurseries.			Infected Nurseries.		
Nursery.	Fruiting Beds with Red-core.	Total Fruiting Beds.	Nursery.	Fruiting Beds with Red-core.	Total Fruiting Beds.
A	1	2	F	8	10
B	0	5	G	1	7
C	0	2	H	4	4
D	1	4	I	1	4
E	0	3	J	1	1
Total	2	16	Total	15	26

These results indicate that:—

(1) Red-core disease is spread to the fruiting beds on infected plants.

(2) Infection may be present in some apparently clean nurseries and yet not be detected until the plants are grown under wet soil conditions.

(3) Lines which are known to contain infected plants do not necessarily develop red-core in the fruiting beds.

CONTROL

The spores of this fungus are of two kinds, thick-walled oospores which enable the fungus to remain alive in the soil for several years, and smaller thin-walled zoospores which are able to move in the soil water and cause rapid spread of the disease under wet soil conditions. Control measures should aim firstly at preventing infection of clean ground and secondly at reducing spread of the disease. The first can be achieved by growing only plants from red-core free nurseries, while reduction in spread is aided by deep cultivation to improve drainage. By avoiding infected land found by inspecting nurseries in the spring months and by the elimination of low-lying areas, the incidence of red-core may be greatly reduced.

Preliminary experiments in New Zealand on the longevity of infection in the soil have shown that severe red-core may occur after the ground has grown non-susceptible crops for four years. Thus a long rotation is necessary to prevent reinfection.

In both the United States of America (Waldo *et al.*, 1947) and Scotland (Reid, 1944) resistant varieties of strawberries have been developed, and it is possible that these will ultimately provide satisfactory control.

ACKNOWLEDGMENTS

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PREPARATION OF THE CYANOGENETIC GLUCOSIDE OF WHITE CLOVER

By J. MELVILLE and J. G. FRASER, Plant Chemistry Laboratory, Department of Scientific and Industrial Research, Palmerston North

In the course of preparing the glucoside of white clover for the toxicity studies previously reported in this journal (1) unexpected difficulties were encountered in applying the method by which some 50 g. had been previously prepared in this Laboratory (2). Despite the use of the same raw material, equipment and technique, the authors were unable to bring about any significant crystallization of the glucoside from the ethyl acetate extracts.

Finally two methods, neither of which was as elegant or convenient as that previously described, were found to give reasonable yields of crystalline material and were used for the preparation of the 40 g. supplied to Professor Coop. In the first the concentrated clover extract, after clarification with lead acetate, was treated with 0.4 vol. alcohol followed by 2 vol. acetone. The upper layer, which contains about 75 per cent of the glucoside, was evaporated to remove the solvents and shaken out exhaustively with ethyl acetate in the cold. From the concentrated extract the glucoside crystallized readily in yields of about 40 per cent.

The second method utilized dried clover containing about 1.5 per cent glucoside, the procedure being extraction with alcohol, removal of solvent and transference to water, clarification with lead acetate, evaporation practically to dryness and exhaustive extraction of the sticky residue with boiling ethyl acetate. Again no difficulty was encountered in the separation of the glucoside which was isolated in about 60 per cent yield.

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